

8. CHEMICAL MANUFACTURING AND PROCESSING SOURCES

8.1. BLEACHED CHEMICAL WOOD PULP AND PAPER MILLS

In March 1988, EPA and the U.S. pulp and paper industry jointly released the results of a screening study that provided the first comprehensive data on the formation and discharge of CDDs/CDFs from pulp and paper mills (U.S. EPA, 1988d). This early screening study of five bleached kraft mills (the Five Mill Study) confirmed that the pulp bleaching process was primarily responsible for the formation of CDDs/CDFs. The study results showed that 2,3,7,8-TCDD was present in seven of nine bleached pulps, five of five wastewater treatment sludges, and three of five treated wastewater effluents. The study results also indicated that 2,3,7,8-TCDD and 2,3,7,8-TCDF were the principal CDDs/CDFs formed.

To provide EPA with more complete data on the release of these compounds by the U.S. industry, EPA and the U.S. pulp and paper industry jointly conducted a survey during 1988 of 104 pulp and paper mills in the United States to measure levels of 2,3,7,8-TCDD and 2,3,7,8-TCDF in effluent, sludge, and pulp. That study, commonly called the 104 Mill Study, was managed by the National Council of the Paper Industry for Air and Stream Improvement, Inc. (NCASI), with oversight by EPA, and included all mills where chemically produced wood pulps were bleached with chlorine or chlorine derivatives. The final study report (U.S. EPA, 1990a) was released in July 1990.

An initial phase of the 104 Mill Study involved the analysis of bleached pulp (10 samples), wastewater sludge (9 samples), and wastewater effluent (9 samples) from eight kraft mills and one sulfite mill for all 2,3,7,8-substituted CDDs/CDFs. These analyses were conducted to test the conclusion drawn in the Five Mill Study that 2,3,7,8-TCDD and 2,3,7,8-TCDF were the principal CDDs/CDFs found in pulp, wastewater sludge, and wastewater effluent on a TEQ basis. Although at the time of the study there were no reference analytical methods for many of the 2,3,7,8-substituted CDDs/CDFs, the data obtained were considered valid by EPA for the purposes intended because of the identification and quantification criteria used, duplicate sample results, and limited matrix spike experiments. Table 8-1 presents a summary of the results obtained in terms of the median concentrations and the range of concentrations observed for each matrix (pulp, sludge, and effluent). Figures 8-1 through 8-3 present congener profiles for each matrix (normalized to total CDD/CDF and total I-TEQ_{DF}) using the median reported concentrations.

1 After examination of the raw, mill-specific data, EPA (U.S. EPA, 1990a) concluded that
2 the congener profiles were fairly consistent across matrices within mills and that 2,3,7,8-TCDD
3 and 2,3,7,8-TCDF accounted for the majority of TEQ in the samples. Using the median
4 concentrations and treating nondetect values as either zero or one-half the detection limit (DL),
5 EPA concluded that 2,3,7,8-TCDF accounted for 95.4 to 99.5% of the total TEQ_{DF}-WHO₉₈ (95.8
6 to 99% of the total I-TEQ_{DF}) in pulp, 94.1 to 96.5% of the TEQ_{DF}-WHO₉₈ (94.1 to 95.8% of the
7 I-TEQ_{DF}) in sludge, and 81.7 to 96.4% of the TEQ_{DF}-WHO₉₈ (81.1 to 91.7% of the I-TEQ_{DF}) in
8 effluent.

9 NCASI reported on a similar full-congener analysis study for samples collected from
10 eight mills during the mid-1990s (Gillespie, 1997). The results of these analyses are presented in
11 Table 8-2. The frequency of detection of 2,3,7,8-TCDD and 2,3,7,8-TCDF was significantly
12 lower than in the 1988 study; therefore, deriving meaningful summary statistics concerning the
13 relative importance of 2,3,7,8-TCDD and 2,3,7,8-TCDF to the total TEQ is difficult. With all
14 nondetect values assumed to be zero, 2,3,7,8-TCDD and 2,3,7,8-TCDF accounted for 97% of the
15 total effluent TEQ_{DF}-WHO₉₈ (91% of the I-TEQ_{DF}), 53% of the total sludge TEQ_{DF}-WHO₉₈
16 (46% of the I-TEQ_{DF}), and 87% of the total pulp TEQ_{DF}-WHO₉₈ (87% of the I-TEQ_{DF}). Because
17 of the high frequency of nondetects when all nondetect values are one-half the DL, 2,3,7,8-
18 TCDD and 2,3,7,8-TCDF accounted for only 13% of the total effluent I-TEQ_{DF}, 13% of the total
19 sludge I-TEQ_{DF}, and 28% of the total pulp I-TEQ_{DF}.

20 In 1992, the pulp and paper industry conducted its own NCASI-coordinated survey of
21 2,3,7,8-TCDD and 2,3,7,8-TCDF emissions (NCASI, 1993). Ninety-four mills participated in
22 the study, and NCASI assumed that the remaining 10 (of 104) operated at the same levels as
23 measured in the 1988 104 Mill Study. All nondetect values were counted as one-half the DL. If
24 a DL was not reported, it was assumed to be 10 pg/L for effluent and 1 ng/kg for sludge or
25 bleached pulp. The data used in the report were provided by individual pulp and paper
26 companies that had been requested by NCASI to generate the data using the same protocols used
27 in the 104 Mill Study.

28 In 1993, as part of its efforts to develop revised effluent guidelines and standards for the
29 pulp, paper, and paperboard industry, EPA published the development document for the
30 guidelines and standards being proposed for this industry (U.S. EPA, 1993d). The development
31 document presented estimates of the 2,3,7,8-TCDD and 2,3,7,8-TCDF annual discharges in
32 wastewater from the mills in this industry as of January 1, 1993. To estimate these discharges,

1 EPA used the most recent information about each mill from four databases (104 Mill Study, EPA
2 short-term monitoring studies at 13 mills, EPA long-term monitoring studies at eight mills, and
3 industry self-monitoring data submitted to EPA). The 104 Mill Study data were used for only
4 those mills that did not report making any process changes subsequent to the 104 Mill Study and
5 did not submit any more recent effluent monitoring data.

6 Gillespie (1994) and Gillespie (1995) reported the results of 1993 and 1994 updates,
7 respectively, to the 1992 NCASI survey. As in the 1992 survey, companies were requested to
8 follow the same protocols for generating data used in the 104 Mill Study. Gillespie (1994, 1995)
9 reported that fewer than 10% of mills had 2,3,7,8-TCDD and 2,3,7,8-TCDF concentrations in
10 effluent above the nominal DLs of 10 pg/L and 100 pg/L, respectively. EPA obtained similar
11 results in its short- and long-term sampling for 18 mills; 2,3,7,8-TCDD was detected at four
12 mills, and 2,3,7,8-TCDF was detected at nine mills (U.S. EPA, 1993d).

13 Gillespie (1994) reported that wastewater sludges at most mills (90%) contained less than
14 31 ng/kg of 2,3,7,8-TCDD and less than 100 ng/kg of 2,3,7,8-TCDF. Gillespie (1995) reported
15 that 90% of the mills had 2,3,7,8-TCDD and 2,3,7,8-TCDF concentrations in sludge of less than
16 17 ng/kg and 76 ng/kg, respectively, in 1994. U.S. EPA (1993d) reported similar results but
17 found detectable levels of 2,3,7,8-TCDD and 2,3,7,8-TCDF in sludges from 64% and 85%,
18 respectively, of the facilities sampled.

19 In Gillespie (1994), nearly 90% of the bleached pulps contained less than 2 ng/kg of
20 2,3,7,8-TCDD and less than 160 ng/kg of 2,3,7,8-TCDF. Gillespie (1995) reported that 90% of
21 the bleached pulps contained 1.5 ng/kg or less of 2,3,7,8-TCDD and 5.9 ng/kg or less of 2,3,7,8-
22 TCDF. The final levels in white paper products would correspond to levels in bleached pulp, so
23 bleached paper products would also be expected to contain less than 2 ng/kg of 2,3,7,8-TCDD.

24 On April 15, 1998, EPA promulgated effluent limitations guidelines and standards for
25 certain segments of the pulp, paper, and paperboard industry (Federal Register, 1998c). The
26 industry segments covered by this rulemaking (i.e., the bleached paper-grade kraft and soda
27 subcategory and the paper-grade sulfite subcategory) are those segments responsible for more
28 than 90% of the bleached chemical pulp production in the United States. For this rule, EPA
29 updated the estimates of baseline loadings made in 1993 for the proposed rule by using more
30 recent data collected by EPA, NCASI (including the 1994 NCASI survey), and individual
31 facilities (U.S. EPA, 1997f). These revised estimates are presented in the last column in Table 8-

3. EPA projects that, after full compliance with these rules, annual TEQ discharges will be reduced to 5 g in effluent and 7 g in sludge.

8.1.1. Estimates of National Emissions in 1987 and 1995

The U.S. annual discharges of 2,3,7,8-TCDD and 2,3,7,8-TCDF are summarized in Table 8-3 for each of the six surveys discussed above. EPA release estimates for 1988 (U.S. EPA, 1990a) and for 1995 (U.S. EPA, 1997f) are believed to best represent emissions in reference years 1987 and 1995, respectively. During the period between EPA's 104 Mill Study and issuance of the development document (U.S. EPA, 1993d), the U.S. pulp and paper industry reduced releases of CDDs/CDFs, primarily by instituting numerous process changes to reduce the formation of CDDs/CDFs during the production of chemically bleached wood pulp. Details on the process changes implemented are provided in U.S. EPA (1993d) and Gillespie (1995). Much of the reduction between 1988 and 1995 can be attributed to process changes for pollution prevention.

The confidence ratings for these release estimates are judged to be high because direct measurements were made at virtually all facilities, indicating a high level of confidence in both the production and the emission factor estimates. The best estimates of annual emissions in 1987 (i.e., the 1988 estimates presented in Table 8-3) are 356 g TEQ/yr for effluent and 343 g TEQ/yr for sludge. The best estimates of annual emissions in 1995 (i.e., the 1995 estimates presented in Table 8-3) are 28 g TEQ/yr for effluent and 50 g TEQ/yr for sludge. The CDD/CDF content in bleached chemical wood pulp as a product is estimated to be approximately 505 g TEQ and 40 g TEQ in 1987 and 1995, respectively. Although EPA provided an estimate of contaminant levels of CDDs/CDFs in wood pulp, it is currently not known if the dioxin contamination in the product actually resulted in a release to the open and circulating environment.

In 1990, the majority (75.5%) of the wastewater sludge generated by these facilities was placed in landfills or in surface impoundments, with the remainder incinerated (20.5%), applied to land directly or as compost (4.1%), or distributed as a commercial product (less than 1%) (U.S. EPA, 1993e). Data on the disposition of wastewater sludges are available only for years 1988 through 1995. On the basis of these data, the best estimate of TEQ applied to land (i.e., not incinerated or landfilled) is 14.1 g TEQ (4.1% of 343 g) for 1987 and 2 g (4.1% of 50 g) for 1995. These emission estimates are assigned a high level of confidence on the basis of the high confidence ratings given to both the activity level and emission factor estimates.

8.1.2. Estimates of National Emissions in 2000

In 2000, NCASI provided estimates of congener-specific CDD/CDF releases from the pulp and paper industry in effluent, wastewater residuals, and pulp (Gillespie, 2002). Emission factors were taken from the “NCASI Handbook of Chemical Specific Information for SARA (Superfund Amendments and Reauthorization Act) Section 313 Form R Reporting.” Emission factors were compiled from valid test data supplied to NCASI by a variety of sources, including member companies that had performed the tests in response to a regulatory program. The mass throughput parameter of total pulp production (31.9 million metric tons/yr) was provided by the American Forest and Paper Association and included data from 12 elemental chlorine-free mills. The effluent flow from chemical pulp mills with aerated stabilization basins (1509 million gal/day) and with activated sludge treatment (660 million gal/day) was taken from the NCASI database and included data from five aerated stabilization basin mills and three activated sludge treatment mills. The primary waste treatment residuals from pulp mills (0.974 million dry metric tons/yr) and the combined, secondary, and dredged waste treatment residuals from pulp mills (1.37 million dry metric tons/yr) were also taken from the NCASI database and included data from five mills for the primary residuals and data from three mills for the secondary residuals (Gillespie, 2002).

Table 8-4 provides a breakdown of $TEQ_{DF-WHO_{98}}$ concentrations and emissions by congener. Total $TEQ_{DF-WHO_{98}}$ concentrations were reported to be 0.49 pg/L, 1.72 ng/kg, and 0.02 pg/g for effluent, sludge, and pulp, respectively. CDD/CDF emission estimates were reported as 1.02 g $TEQ_{DF-WHO_{98}}$ /yr, 1.93 g $TEQ_{DF-WHO_{98}}$ /yr, and 0.582 g $TEQ_{DF-WHO_{98}}$ /yr for effluent, sludge, and pulp, respectively.

Fifty-one percent of the sludge generated was sent to landfills or lagoons. It is uncertain how much of the remaining 49% of the sludge was applied to land. However, a conservative estimate can be developed by applying the 4.1% used to develop the 1987 and 1995 estimates. In this case, 0.08 g $TEQ_{DF-WHO_{98}}$ /yr of sludge is estimated to have been applied to land in 2000. These estimates are assigned a high confidence rating because they are based on recent industry survey data; however, EPA is working with NCASI to develop a QA/QC protocol to monitor the data being collected.

8.2. MANUFACTURE OF CHLORINE, CHLORINE DERIVATIVES, AND METAL CHLORIDES

Testing of CDD/CDF emissions to air, land, or water from U.S. manufacturers of chlorine, chlorine derivatives, and metal chlorides on which to base estimates of national emissions has not been reported. Sampling of graphite electrode sludges from European chlorine manufacturers indicates high levels of CDFs. Limited sampling of chlorine derivatives and metal chlorides in Europe indicates low-level contamination in some products.

8.2.1. Manufacture of Chlorine

Chlorine gas is produced by electrolysis of brine electrolytic cells. Until the late 1970s, the primary type of electrolytic process used in the chloralkali industry to produce chlorine consisted of the use of mercury cells containing graphite electrodes. As shown in Table 8-5, high levels of CDFs have been found in several samples of graphite electrode sludge from facilities in Europe. The CDFs predominate in these sludges, and the 2,3,7,8-substituted congeners account for a large fraction of the respective congener totals (Rappe et al., 1990b, 1991; Rappe, 1993; Strandell et al., 1994). During the 1980s, titanium metal anodes were developed to replace graphite electrodes (U.S. EPA, 1982a; Curlin and Bommaraju, 1991). Currently, no U.S. facility is believed to use graphite electrodes in the production of chlorine gas (telephone conversation between L. Phillips, Versar, Inc., and T. Fielding, U.S. EPA, Office of Water, February 1993).

Although the origin of the CDFs in graphite electrode sludge is uncertain, chlorination of the cyclic aromatic hydrocarbons (such as dibenzofuran) present in the coal tar used as a binding agent in the graphite electrodes has been proposed as the primary source (Strandell et al., 1994). For this reason, sludges produced using metal electrodes were not expected to contain CDFs. However, results of an analysis of metal electrode sludge from a facility in Sweden, analyzed as part of the Swedish Dioxin Survey, showed that the sludge contained high levels of CDFs (similar to those of the graphite sludge) and primarily nondetectable levels of CDDs (Strandell et al., 1994). The sludge showed the same type of CDF congener pattern reported by Rappe et al. (1991) and Rappe (1993). Strandell et al. (1994) suggested that chlorination of polyaromatic hydrocarbons present in the rubber linings of the electrolytic cell may have formed the CDFs found in the one sample analyzed.

1 Although EPA does not regulate CDDs/CDFs specifically, it issued restrictions under the
2 Resource Conservation and Recovery Act (RCRA) on the land disposal of wastewater and
3 sludges generated by chlorine manufacturers that use the mercury cell process and the diaphragm
4 process (with graphite electrodes) (waste codes K071, K073, and K106) (40 CFR 268).

6 **8.2.2. Manufacture of Chlorine Derivatives and Metal Chlorides**

7 The limited sampling of chlorine-derivative products indicates that they contain very low,
8 if any, concentrations of CDDs/CDFs. Rappe et al. (1990c) analyzed a sample of chlorine bleach
9 consisting of 4.4% sodium hypochlorite. Most of the 2,3,7,8-substituted CDD/CDF congeners
10 were below the limits of detection (0.3 to 7 pg/L for all congeners except OCDD and OCDF,
11 which were 12 and 20 pg/L, respectively). No 2,3,7,8-substituted CDDs were detected. Tetra-,
12 penta-, and hexa-CDFs were detected at levels of 13 pg/L or lower. The TEQ content of the
13 sample was 4.9 pg I-TEQ_{DF}/L. Hutzinger and Fiedler (1991a) reported finding no CDDs/CDFs
14 at a detection limit of 4 µg/kg in chlorine gas or in samples of 10% sodium hypochlorite, 13%
15 sodium hypochlorite, and 31 to 33% hydrochloric acid at a detection limit of 1 µg/kg.

16 Hutzinger and Fiedler (1991a) reported the results of analyses of samples of ferric
17 chloride (FeCl₃), aluminum trichloride (AlCl₃), CuCl₂, CuCl, silicon tetrachloride (SiCl₄), and
18 titanium tetrachloride (TiCl₄) for their content of HpCDF, OCDF, HpCDD, and OCDD. The
19 sample of FeCl₃ contained HpCDF and OCDF in the low µg/kg range, but no HpCDD or OCDD
20 was detected at a DL of 0.02 µg/kg. One of the two samples of AlCl₃ analyzed also contained a
21 low (µg/kg) concentration of OCDF. The samples of CuCl₂ and CuCl contained concentrations
22 of HpCDF, OCDF, and OCDD of less than 1 µg/kg. The results are presented in Table 8-6.

24 **8.3. MANUFACTURE OF HALOGENATED ORGANIC CHEMICALS**

25 Several chemical production processes generate CDDs/CDFs (Versar, 1985; Hutzinger
26 and Fiedler, 1991a). CDDs/CDFs can be formed during the manufacture of chlorophenols,
27 chlorobenzenes, and chlorobiphenyls (Versar, 1985; Ree et al., 1988). Consequently, disposal of
28 industrial wastes from manufacturing facilities producing these compounds may result in the
29 release of CDDs/CDFs to the environment. Also, the products themselves may contain these
30 compounds, and their use or consumption may result in additional releases to the environment.

31 CDD/CDF congener distribution patterns indicative of noncombustion sources have been
32 observed in sediments in southwest Germany and the Netherlands. According to Ree et al.

(1988), the congener patterns found suggest that wastes from the production of chlorinated organic compounds may be important historical sources of CDD/CDF contamination in these regions. The production and use of many of the chlorophenols, chlorophenoxy herbicides, and PCB products are now banned or strictly regulated in most countries. However, these products may have been a source of the environmental contamination that occurred prior to the 1970s and may continue to be a source of environmental releases under certain limited use and disposal conditions (Rappe, 1992a).

8.3.1. Chlorophenols

Chlorophenols have been widely used for a variety of pesticidal applications. The more-highly chlorinated phenols (tetra- and pentachlorophenol [PCP]) and their sodium salts have been used primarily for wood preservation. The less-chlorinated phenols have been used primarily as chemical intermediates in the manufacture of other pesticides. For example, 2,4-dichlorophenol is used to produce the herbicides 2,4-dichlorophenoxyacetic acid (2,4-D), 4-(2,4-dichlorophenoxy)butanoic acid (2,4-DB), 2-(2,4-dichlorophenoxy)-propanoic acid (2,4-DP), Nitrophen, Genite, and Zytron, and 2,4,5-trichlorophenol was used to produce hexachlorophene, 2,4,5-T, Silvex, Erbon, Ronnel, and Gardona (Gilman et al., 1988; Hutzinger and Fiedler, 1991a). (Sections 8.3.7 and 8.3.8 contain information on EPA actions to control CDD/CDF contamination of pesticides, including PCP and its salts, and to obtain additional data on CDD/CDF contamination of pesticides.)

The two major commercial methods used to produce chlorophenols are (1) electrophilic chlorination of molten phenol by chlorine gas in the presence of catalytic amounts of a metal chloride and organic chlorination promoters and stabilizers, and (2) alkaline hydrolysis of chlorobenzenes under heat and pressure using aqueous methanolic sodium hydroxide. Other manufacturing methods include conversion of diazonium salts of various chlorinated anilines and chlorination of phenolsulfonic acids and benzenesulfonic acids, followed by the removal of the sulfonic acid group (Gilman et al., 1988; Hutzinger and Fiedler, 1991a).

Because of the manufacturing processes employed, commercial chlorophenol products can contain appreciable amounts of impurities (Gilman et al., 1988). During the direct chlorination of phenol, CDDs/CDFs can form either by the condensation of tri-, tetra-, and pentachlorophenols or by the condensation of chlorophenols with hexachlorocyclohexadienone (which forms from excessive chlorination of phenol). During alkaline hydrolysis of

chlorobenzenes, CDDs/CDFs can form through chlorophenolate condensation (Ree et al., 1988; Gilman et al., 1988; Hutzinger and Fiedler, 1991a).

The limited information on CDD/CDF concentrations in chlorophenols published in the 1970s and early 1980s was compiled by Versar (1985) and Hutzinger and Fiedler (1991a). The results of several major studies cited by these reviewers (Firestone et al., 1972; Rappe et al., 1978a, 1978b) are presented in Table 8-7. Typically, CDDs/CDFs were not detected in monochlorophenols and dichlorophenols (DCP) but were reported in trichlorophenols (TrCP) and tetrachlorophenols (TeCP). More recent results of testing of 2,4-dichlorophenol (2,4-DCP), performed in response to the Toxic Substances Control Act (TSCA) dioxin/furan test rule, showed no detectable concentrations of 2,3,7,8-substituted tetra- through hepta-CDD/CDFs.

Other than a study by Hagenmaier (1986) that reported finding 2,3,7,8-TCDD at a concentration of 0.3 µg/kg in a sample of 2,3,4,5-tetrachlorophenol, no more recent data on concentrations of CDDs and CDFs could be found in the literature for the mono- through tetra-chlorophenols. Tables 8-8 and 8-9 present summaries of several studies that reported CDD/CDF concentrations in PCP and in PCP-Na products, respectively. Many of these studies do not report congener-specific concentrations, and many are based on products obtained from non-U.S. sources.

8.3.1.1. Regulatory Actions for Chlorophenols

Section 8.3.8 of this report describes regulatory actions taken by EPA to control the manufacture and use of chlorophenol-based pesticides. In the mid-1980s, EPA's Office of Solid Waste (OSW) promulgated, under RCRA, land disposal restrictions on wastes (wastewaters and nonwastewaters) resulting from the manufacture of chlorophenols (40 CFR 268). Table 8-10 lists all wastes in which CDDs/CDFs are specifically regulated by EPA as hazardous constituents, including chlorophenol wastes (waste codes F020 and F021). The regulations prohibit the land disposal of these wastes until they are treated to a level below the routinely achievable DLs in the waste extract listed in Table 8-10 for each of the following congener groups: TCDDs, PeCDDs, HxCDDs, TCDFs, PeCDFs, and HxCDFs. Wastes from PCP-based wood-preserving operations (waste codes K001 and F032) are also regulated as hazardous wastes under RCRA (40 CFR 261).

EPA's Office of Water promulgated effluent limitations for facilities that manufacture chlorinated phenols and discharge treated wastewater (40 CFR 414.70). These effluent

1 limitations do not specifically regulate CDDs or CDFs. The effluent limitations for the
2 individually regulated chlorinated phenols are less than or equal to 39 µg/L for facilities that use
3 biological end-of-pipe treatment.

4 DCPs and TrCPs are subject to reporting under the dioxin/furan test rule, which is
5 discussed in Section 8.3.7 of this report. Since the effective date of that rule (June 5, 1987), only
6 the 2,4-DCP isomer has been commercially produced in (or imported to) the United States, and
7 as noted in Table 8-7, no CDDs/CDFs were detected in the product. Testing is required for the
8 other DCPs and TrCPs, if manufacture or importation resumes. Similarly, TeCPs were subject to
9 reporting under the Dioxin/Furan Pesticide Data Call-In (DCI) (discussed in Section 8.3.8 of this
10 report). Since issuance of the DCI, the registrants of TeCP-containing pesticide products have
11 elected to no longer support the registration of their products in the United States.

12 In January 1987, EPA entered into a settlement agreement with PCP manufacturers that
13 set limits, effective in February 1989, on the allowed uses of PCP and its salts and the maximum
14 allowable concentrations of 2,3,7,8-TCDD and HxCDDs. Section 8.3.8 discusses the 1987 PCP
15 settlement agreement and includes estimates of current releases of CDDs/CDFs associated with
16 use of PCP in the United States. Section 12.3.1 provides an estimate of the amount of
17 CDDs/CDFs that may have entered the environment or that are contained within treated wood
18 products as a result of prior use of PCP and PCP-Na.

19 Since the late 1980s, U.S. commercial production of chlorophenols has been limited to
20 2,4-dichlorophenol (2,4-DCP) and PCP. As noted above, disposal of wastes generated during
21 the manufacture of chlorophenols is strictly regulated, and thus releases to the environment are
22 expected to be negligible. With regard to releases associated with the use of 2,4-DCP, no
23 CDDs/CDFs have been detected in 2,4-DCP. Releases associated with the use of PCP are
24 presented in Sections 8.3.8 and 12.3.1.

25 26 **8.3.2. Chlorobenzenes**

27 Chlorobenzenes have been produced in the United States since 1909. U.S. production
28 operations were developed primarily to provide chemical raw materials for the production of
29 phenol, aniline, and various pesticides based on the higher chlorinated benzenes. Because of
30 (incremental) changes in the processes used to manufacture phenol and aniline and the phaseout
31 of highly chlorinated pesticides such as DDT and hexachlorobenzene, U.S. production of
32 chlorobenzenes in 1988 had decreased to 50% of the peak production level, in 1969.

1 Chlorobenzenes can be produced via three methods: (1) electrophilic substitution of
2 benzene (in liquid or vapor phase) with chlorine gas in the presence of a metal salt catalyst, (2)
3 oxidative chlorination of benzene with HCl at 150 to 300 °C in the presence of a metal salt
4 catalyst, and (3) dehydrohalogenation of hexachlorocyclohexane wastes at 200 to 240 °C with a
5 carbon catalyst to produce trichlorobenzene, which can be further chlorinated to produce more-
6 highly chlorinated benzenes (Ree et al., 1988; Hutzinger and Fiedler, 1991a; Bryant, 1993).

7 All chlorobenzenes currently manufactured in the United States are produced by the
8 electrophilic substitution process using liquid-phase benzene (i.e., temperature is at or below
9 80 °C). Ferric chloride is the most common catalyst employed. Although this method can be
10 used to produce mono- through hexachlorobenzene, the extent of chlorination is controlled to
11 yield primarily monochlorobenzene (MCBz) and dichlorobenzene (DCBz). The finished product
12 is a mixture of chlorobenzenes, and refined products must be obtained by distillation and
13 crystallization (Bryant, 1993).

14 CDDs/CDFs can be produced inadvertently during the manufacture of chlorobenzenes by
15 nucleophilic substitution and pyrolysis mechanisms (Ree et al., 1988). The criteria required for
16 production of CDDs/CDFs via nucleophilic substitution are (1) oxygen as a nuclear substituent
17 (i.e., presence of chlorophenols) and (2) production or purification of the substance under
18 alkaline conditions. Formation via pyrolysis requires reaction temperatures above 150 °C (Ree
19 et al., 1988; Hutzinger and Fiedler, 1991a). The liquid-phase electrophilic substitution process
20 currently used in the United States does not meet either of these criteria. Although Ree et al. and
21 Hutzinger and Fiedler state that the criteria for formation of CDDs/CDFs via nucleophilic
22 substitution may be present in the catalyst neutralization and purification/distillation steps of the
23 manufacturing process, Opatick (1995) states that the chlorobenzene reaction product in U.S.
24 processes remains mildly acidic throughout these steps.

25 Table 8-11 summarizes the very limited published information on CDD/CDF
26 contamination of chlorobenzene products. The presence of CDDs/CDFs has been reported in
27 TCBz, PeCBz, and HCBz. No CDDs/CDFs have been reported in MCBz or DCBz. Conflicting
28 data exist concerning the presence of CDDs/CDFs in TCBz. One study (Villanueva et al., 1974)
29 detected no CDDs/CDFs in one sample of 1,2,4-TCBz at a DL of 0.1 µg/kg. Hutzinger and
30 Fiedler (1991a) reported unpublished results of Dr. Hans Hagenmaier showing CDD/CDF
31 congener group concentrations ranging from 0.02 to 0.074 µg/kg in a sample of mixed TCBz.
32 Because the TCBz examined by Hagenmaier contained about 2% hexachlorocyclohexane, it is

reasonable to assume that the TCBz was produced by dehydrohalogenation of hexachlorocyclohexane (a manufacturing process not currently used in the United States).

8.3.2.1. Regulatory Actions for Chlorobenzenes

EPA determined, as part of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) DCI (discussed in Section 8.3.8), that the 1,4-DCBz manufacturing processes used in the United States are not likely to form CDDs/CDFs. MCBz, DCBz, and TCBz are listed as potential precursor chemicals under the TSCA dioxin/furan test rule and are subject to reporting (see Section 8.3.7). In addition, EPA issued a Significant New Use Rule (SNUR) under Section 5(a)(2) of TSCA on December 1, 1993 (effective January 14, 1994) for PeCBz and 1,2,4,5-TeCBz (Federal Register, 1993c). This rule requires persons to submit a notice to EPA at least 90 days before manufacturing, importing, or processing either of these compounds in amounts of 10,000 pounds or greater per year per facility for any use. All registrations of pesticide products containing HCBz were cancelled in the mid-1980s (Carpenter et al., 1986).

OSW promulgated land disposal restrictions on wastes (i.e., wastewaters and nonwastewaters) resulting from the manufacture of chlorobenzenes (40 CFR 268). Table 8-10 lists all solid wastes for which EPA specifically regulates CDDs and CDFs, including chlorobenzene wastes, as hazardous constituents. The regulations prohibit the land disposal of these wastes until they are treated to a level below the routinely achievable DLs in the waste extract listed in Table 8-10 for each of the following congener groups: TCDDs, PeCDDs, HxCDDs, TCDFs, PeCDFs, and HxCDFs.

EPA's Office of Water promulgated effluent limitations for facilities that manufacture chlorinated benzenes and discharge treated wastewater (40 CFR 414.70). These effluent limitations do not specifically address CDDs and CDFs. The following chlorinated benzenes are regulated: chlorobenzene; 1,2-dichlorobenzene; 1,3-dichlorobenzene; 1,4-dichlorobenzene; 1,2,4-trichlorobenzene; and hexachlorobenzene. The effluent limitations for the individual regulated chlorinated benzenes are less than or equal to 77 µg/L for facilities that use biological end-of-pipe treatment and less than or equal to 196 µg/L for facilities that do not use biological end-of-pipe treatment.

Since at least 1993, U.S. commercial production of chlorobenzenes has been limited to MCBz, 1,2-dichlorobenzene (1,2-DCBz), 1,4-dichlorobenzene (1,4-DCBz), and, to a much lesser extent, 1,2,4-trichlorobenzene (1,2,4-TCBz). As noted above, CDD/CDF formation is not

1 expected under the normal operating conditions of the processes currently used in the United
2 States to produce these four chemicals. No tetra-, penta-, or hexachlorinated benzenes are now
3 intentionally produced or used in the United States (Bryant, 1993). Thus, releases of
4 CDDs/CDFs from the manufacture of chlorobenzenes in 1995 were estimated to be negligible.
5 Because the information available on CDD/CDF content of MCBz to PeCBz is very limited and
6 is based primarily on unpublished European data, and because information on the chlorobenzene
7 manufacturing processes in place during 1987 is not readily available, no emission estimates can
8 be made for 1987.

9 10 **8.3.3. Chlorobiphenyls**

11 PCBs are manufactured by the direct batch chlorination of molten biphenyl in the
12 presence of a catalyst, followed by separation and purification of the desired chlorinated
13 biphenyl fractions. During the manufacture of PCBs, the inadvertent production of CDFs also
14 occurs. This section addresses potential releases of CDDs/CDFs associated with leaks and spills
15 of PCBs. CDFs have been shown to form when PCB-containing transformers and capacitors
16 undergo malfunctions or are subjected to fires that result in accidental combustion of the
17 dielectric fluid. This combustion source of PCB-associated CDFs is discussed in Section 6.6.
18 Section 11.2 addresses releases of dioxin-like PCBs.

19 PCB production is believed to have occurred in 10 countries. The total amount of PCBs
20 produced worldwide since 1929 (i.e., the first year of known production) is estimated to total 1.5
21 billion kg. Initially, PCBs were primarily used as dielectric fluids in transformers. After World
22 War II, PCBs found steadily increasing use as dielectric fluids in capacitors, as heat-conducting
23 fluids in heat exchangers, and as heat-resistant hydraulic fluids in mining equipment and vacuum
24 pumps. PCBs also were used in a variety of "open" applications (i.e., uses from which PCBs
25 cannot be recollected) including plasticizers, carbonless copy paper, lubricants, inks, laminating
26 agents, impregnating agents, paints, adhesives, waxes, additives in cement and plaster, casting
27 agents, dedusting agents, sealing liquids, fire retardants, immersion oils, and pesticides (DeVoogt
28 and Brinkman, 1989).

29 PCBs were manufactured in the United States from 1929 until 1977. U.S. production
30 peaked in 1970, with a volume of 38.56 million kg. Monsanto Corporation, the major U.S.
31 producer, voluntarily restricted the use of PCBs in 1971, and annual production fell to 18.14
32 million kg in 1974. Monsanto Corporation ceased PCB manufacture in mid-1977 and shipped

the last inventory in October 1977. Regulations issued by EPA beginning in 1977, principally under TSCA (40 CFR 761), strictly limited the production, import, use, and disposal of PCBs. (See Section 4.1 for details on TSCA regulations.) The estimated cumulative production and consumption volumes of PCBs in the United States from 1930 to 1975 were 635.03 million kg produced; 1.36 million kg imported (primarily from Japan, Italy, and France); 568.35 million kg sold in the United States; and 68.04 million kg exported (ATSDR, 1993; DeVogt and Brinkman, 1989).

Monsanto Corporation marketed technical-grade mixtures of PCBs primarily under the trade name Aroclor. The Aroclors are identified by a four-digit numbering code in which the last two digits indicate the chlorine content by weight percent. The exception to this coding scheme is Aroclor 1016, which contains only mono- through hexachlorinated congeners with an average chlorine content of 41%. The following list shows the percentages of total Aroclor production, by (Aroclor mixture) during 1957 to 1977, as reported by Brown (1994).

| <u>Aroclor</u> | <u>1957–1977 U.S. Production (%)</u> |
|----------------|--|
| 1221 | 0.96 |
| 1016 | 12.88 |
| 1232 | 0.24 |
| 1242 | 51.76 |
| 1248 | 6.76 |
| 1254 | 15.73 |
| 1260 | 10.61 |
| 1262 | 0.83 |
| 1268 | 0.33 |

The trade names of the major commercial technical-grade mixtures of PCBs manufactured in other countries included *Clophen* (Germany), *Fenclor* and *Apirolino* (Italy), *Kanechlor* (Japan), *Phenoclor* and *Pyrallene* (France), *Sovtel* (USSR), *Delor* and *Delorene* (Czechoslovakia), and *Orophene* (German Democratic Republic) (DeVogt and Brinkman, 1989). Some of the mixtures marketed under these trade names were similar in terms of chlorine content (by weight percent and average number of chlorines per molecule) to various Aroclors,

as shown below. Mixtures that are comparable in terms of chlorine content were marketed under several trade names, as shown below.

| <u>Aroclor</u> | <u>Clophen</u> | <u>Pyralene</u> | <u>Phenoclor</u> | <u>Fenclor</u> | <u>Kanechlor</u> |
|----------------|----------------|-----------------|------------------|----------------|------------------|
| 1232 | | 2000 | | | 200 |
| 1242 | A-30 | 3000 | DP-3 | 42 | 300 |
| 1248 | A-40 | | DP-4 | | 400 |
| 1254 | A-50 | | DP-5 | 54 | 500 |
| 1260 | A-60 | | DP-6 | 64 | 600 |

During the commercial production of PCBs, thermal oxidative cyclization under alkaline conditions resulted in the inadvertent production of CDFs in most of the commercial PCB mixtures (Brown et al., 1988; ATSDR, 1993). Bowes et al. (1975a) first reported detection of CDFs in Aroclor products; samples of unused Aroclors manufactured in 1969 and 1970 were found to have CDF (i.e., TCDF through HxCDF) concentrations ranging from 0.8 to 2 mg/kg. Bowes et al. (1975b) employed congener-specific analytical methodology and detected 2,3,7,8-TCDF and 2,3,4,7,8-PeCDF at concentrations ranging from 0.11 to 0.33 mg/kg and 0.12 to 0.83 mg/kg, respectively, in unused samples of Aroclor 1254 and Aroclor 1260. The presence of CDDs in commercial PCB mixtures, although at much lower concentrations than those of the CDFs, was reported by Hagenmaier (1987) and Malisch (1994). Table 8-12 presents the CDF and CDD congener group concentrations reported by Bowes et al. (1975a) and those reported in subsequent years for unused PCBs by Erickson (1986), ATSDR (1993), Hagenmaier (1987), and Malisch (1994).

Several researchers reported concentrations of specific CDD/CDF congeners in commercial PCB mixtures (Bowes et al., 1975b; Brown et al., 1988; Hagenmaier, 1987; Malisch, 1994). Table 8-13 presents the results of these four studies. Only the Hagenmaier (1987) and Malisch (1994) studies, however, reported the concentrations of all 2,3,7,8-substituted CDDs and CDFs. It is evident from the table that major variations are found in the levels of 2,3,7,8-TCDF and 2,3,4,7,8-PeCDF in the Clophen mixtures reported by Hagenmaier (1987) and Malisch (1994) and the corresponding levels in the Aroclor mixtures reported by Bowes et al. (1975b) and Brown et al. (1988).

Brown et al. (1988) compared the levels of 2,3,7,8-TCDF; 2,3,4,7,8-PeCDF; and 1,2,3,7,8,9-HxCDF in used samples (i.e., samples from previously used capacitors and transformers) and unused samples of Aroclors 1016, 1242, 1254, and 1260. The concentration

1 ranges reported for the used and unused Aroclors were similar, leading Brown et al. (1988) to
2 conclude that CDFs are not formed during the normal use of PCBs in electrical equipment.

3 Amounts of CDD/CDF TEQ emissions that may have been released to the environment
4 during 1987, 1995, and 2000 from spills and leaks of in-service PCBs cannot be accurately
5 estimated because reliable data regarding leaked and spilled PCBs are not available.

6 7 **8.3.4. Polyvinyl Chloride**

8 PVC resins are produced when free radical initiators are used to induce the
9 polymerization of vinyl chloride monomer (VCM). With the exception of one plant that uses a
10 process involving the catalytic reaction of acetylene and HCl to manufacture VCM directly,
11 VCM is typically produced by the thermal dehydrochlorination (commonly known as cracking)
12 of ethylene dichloride (EDC). The cracking of EDC requires elevated pressure (20 to 30
13 atmospheres) and temperature (450 to 650 °C) and yields VCM and HCl at about a 1:1 molar
14 ratio. EDC is produced by two different methods: (1) direct chlorination of ethylene with
15 chlorine in the presence of a catalyst at a temperature of 50 to 60 °C and pressure of 4 to 5
16 atmospheres, and (2) oxychlorination, which involves reaction of ethylene with HCl and oxygen
17 in the presence of a catalyst at temperatures generally less than 325 °C. The primary source of
18 HCl for the oxychlorination process is the HCl produced from the cracking of EDC to form
19 VCM. All VCM plants, with the exception of the one facility noted above, are integrated with
20 EDC production facilities (Vinyl Institute, 1998).

21 Although it has generally been recognized that CDDs/CDFs are formed during the
22 manufacture of EDC, VCM, and PVC, manufacturers and environmental public interest groups
23 have disagreed as to the quantity of CDDs/CDFs that are formed and released to the environment
24 in wastes and possibly in PVC products. Although EPA regulates emissions from EDC/VCM
25 production facilities under the Clean Water Act (40 CFR 61), the Clean Air Act (40 CFR 414),
26 and RCRA (40 CFR 268, waste codes F024, K019, and K020), CDDs/CDFs are not specifically
27 regulated pollutants; as a consequence, monitoring data for CDDs/CDFs in emissions are
28 generally lacking.

29 In 1993, Greenpeace International issued a report on CDD/CDF emissions associated
30 with the production of EDC/VCM (Greenpeace, 1993). Greenpeace estimated that 5 to 10 g I-
31 TEQ_{DF} are released to the environment (air, water, and ground combined) annually for every
32 100,000 metric tons of VCM produced. This emission factor was based on data gathered by

1 Greenpeace on four European plants. The Vinyl Institute responded with a critique of the
2 Greenpeace report (ChemRisk, 1993). Miller (1993) summarized the differing views of the two
3 parties. According to Miller, European PVC manufacturers claimed the emission factor was 0.01
4 to 0.5 g I-TEQ_{DF}/100,000 metric tons of VCM, but although Greenpeace and ChemRisk used
5 basically the same monitoring information to develop their emission factors, Greenpeace
6 adjusted the emission factor to account for unquantified fugitive emissions and waste products
7 that contain unspecified amounts of CDDs/CDFs.

8 In 1995, Greenpeace issued another report (Stringer et al., 1995) reiterating the
9 organization's concern that the generation and emission of CDDs/CDFs may be significant and
10 urging that further work be initiated to quantify and prevent emissions. Stringer et al. (1995)
11 presented the results of analyses of three samples of chlorinated wastes obtained from U.S.
12 EDC/VCM manufacturing facilities. The three wastes were characterized according to EPA
13 hazardous waste classification numbers as an F024 waste (waste from the production of short-
14 chain aliphatics by free radical catalyzed processes), a K019 waste (heavy ends from the
15 distillation of ethylene from EDC production), and a probable K020 waste (heavy ends from
16 distillation of VC in VCM manufacture). Table 8-14 presents the analytical results reported by
17 Stringer et al. (1995). This study acknowledged that because EDC/VCM production
18 technologies and waste treatment and disposal practices are very site-specific, the limited
19 information available on CDD/CDF generation and emissions made it difficult to quantify
20 amounts of CDDs/CDFs generated and emitted.

21 In response to the lack of definitive studies, and at the recommendation of EPA, U.S.
22 PVC manufacturers initiated an extensive monitoring program, the Dioxin Characterization
23 Program, to evaluate the extent of any CDD/CDF releases to air, water, and land, as well as any
24 product contamination. Manufacturers performed emission and product testing at various
25 facilities that were representative of various manufacturing and process control technologies. In
26 1998, the Vinyl Institute completed studies of CDD/CDF releases in wastewater, wastewater
27 treatment plant solids, and stack gases, as well as studies of CDD/CDF content of products (i.e.,
28 PVC resins and EDC sold as products) (Vinyl Institute, 1998).

29 After the completion of the studies, the Vinyl Institute created an external advisory group
30 to advise the institute on the conduct of the Dioxin Characterization Program and to provide an
31 independent review of the program results. In its final evaluation report, the advisory group
32 judged the industry's coverage to be fairly comprehensive in terms of the number of facilities

1 and waste streams sampled. The number of samples of PVC product, stack emissions,
2 wastewaters, and wastewater sludges obtained from the different types of manufacturing
3 facilities was deemed by the advisory group to provide a sufficient database to evaluate annual
4 industry releases. The advisory group concluded that the process established by the Vinyl
5 Institute to ensure that data collected as part of its Dioxin Characterization Program were
6 representative of normal process operations was a good one. After auditing the Vinyl Institute's
7 estimates of annual releases, the advisory group concluded that the data were properly validated
8 and that the results were extrapolated to annual industry release estimates in a creditable
9 scientific manner.

10 EPA reviewed the Vinyl Institute (1998) studies and concurred with the conclusions of
11 the external advisory group. EPA assigned a high confidence rating to the activity level
12 estimates and a medium confidence rating to the emission factor estimates developed by the
13 Vinyl Institute.

14 In September 2002, the Chlorine Chemistry Council (CCC) met to review dioxin release
15 estimates for 2000 for various EDC/VCM manufacturing facilities. Several companies provided
16 stack gas emissions and wastewater emissions data, as well as a discussion of how they
17 generated the release and transfer estimates reported in the TRI for 2000. In March 2004, the
18 CCC met again to discuss the results, to date, of the Chlorine Chemistry Council CDD/CDF Data
19 Validation Study for PVC/EDC/VCM and chlor-alkali facilities. The study's goal was to
20 provide facility-specific water, air, and land release estimates for the years 2000 and 2002. As of
21 the date of this report, data validation studies were provided for 16 of 20 facilities in the CCC
22 that were considered chlor-alkali production facilities and PVC/EDC/VCM manufacturing
23 plants.

24 25 **8.3.4.1. Wastewater**

26 The Vinyl Institute (1998) presented results for treated wastewater samples collected
27 during April and May of 1995 at six sites that manufactured only PVC, at three sites that
28 manufactured EDC and VCM, and at one site that manufactured EDC, VCM, and PVC. In terms
29 of production, the six PVC-only sites represent approximately 15% of the total estimated 1995
30 U.S. and Canadian PVC production. Together, the three EDC/VCM sites and the one
31 EDC/VCM/PVC site represent 27% of the total estimated 1995 U.S. EDC production. Samples
32 taken from PVC-only sites were taken from sites that manufactured suspension PVC resin as

well as those that manufactured dispersion PVC resin. Samples for the other four sites were taken from sites that used direct and oxychlorination processes, fixed and fluidized beds, and low- and high-temperature direct chlorination. The wastewater samples from one of the EDC/VCM sites, one of the PVC-only sites, and the EDC/VCM/PVC site were taken from effluents derived from process areas not limited to EDC/VCM, EDC/VCM/PVC, or PVC manufacturing.

The results of the sampling are presented in Table 8-15. In all samples, the method detection limit (MDL) for all congeners except OCDD and OCDF was 10 pg/L or less. The MDL for OCDD and OCDF was 50 pg/L or less. CDDs/CDFs were detected in two of the six samples from PVC-only sites (0.52 and 2 pg I-TEQ_{DF}/L, assuming nondetect values are equal to zero [ND = 0]). The overall mean TEQ concentrations were 0.88 pg I-TEQ_{DF}/L (assuming ND = 0) and 4.7 pg I-TEQ_{DF}/L (assuming ND = 1/2 MDL). CDDs/CDFs were detected in all four of the samples from EDC/VCM/PVC sites. The overall mean TEQ concentrations were 0.42 pg I-TEQ_{DF}/L (assuming ND = 0) and 4.4 pg I-TEQ_{DF}/L (assuming ND = 1/2 MDL).

Using these sample results, the Vinyl Institute developed I-TEQ_{DF} emission factors for the two site categories: PVC-only and EDC/VCM/PVC manufacturing facilities. First, individual site release rates were estimated using the treated wastewater effluent flow rate recorded by the site during sampling, assuming that the site continuously released CDDs/CDFs at its calculated total I-TEQ_{DF}, 24 hr/day, 360 day/yr, at the recorded water effluent rate. The total releases from each site category (PVC-only or EDC/VCM/PVC facilities) were then estimated by averaging the individual release rates per 1000 metric ton of PVC or EDC using the estimated 1995 PVC and EDC production statistics for the sampled sites. These values were then scaled up to estimate total U.S. releases in treated wastewater from the site categories. It is not possible using the data presented in the Vinyl Institute study to calculate emission factors for TEQ_{DF}-WHO₉₈. However, because 1,2,3,7,8-PeCDD was not detected in any wastewater sample, the TEQ_{DF}-WHO₉₈ emission factors would be lower than the I-TEQ_{DF} emission factors.

The mean emission factors derived from the sample results for the PVC-only facilities are 2.3 µg I-TEQ_{DF}/1,000 metric tons of PVC (ND = 0) and 29 µg I-TEQ_{DF}/1,000 metric tons of PVC (ND = 1/2 MDL). The mean emission factors for the EDC/VCM/PVC facilities are 2.9 µg I-TEQ_{DF}/1,000 metric tons (ND = 0) and 15 µg I-TEQ_{DF}/1,000 metric tons of EDC (ND = 1/2 MDL).

1 The Vinyl Institute (1998) combined these emission factors with 1995 industry
2 production statistics (5,212 metric tons of PVC and 11,115 metric tons of EDC) to yield release
3 estimates of 0.011 g I-TEQ_{DF} (ND = 0) and 0.15 g I-TEQ_{DF} (ND = 1/2 DL) from PVC-only
4 manufacturing sites and 0.032 g I-TEQ_{DF} (ND = 0) and 0.17 g I-TEQ_{DF} (ND = 1/2 DL) from
5 EDC/VCM and EDC/VCM/PVC facilities for a total I-TEQ_{DF} release to water in 1995 of 0.043 g
6 (ND = 0) and 0.32 g (ND = 1/2 DL).

7 Data validation studies of the CCC provided water release estimates for 16 facilities that
8 were considered chlor-alkali production facilities and PVC/EDC/VCM manufacturing plants
9 (CCC, 2004). Half of these facilities were not involved with the production of PVC/EDC/VCM.
10 Tables 8-16 and 8-17 depict the congener-specific data associated with the water releases from
11 the PVC/EDC/VCM manufacturing plants and the chlor-alkali production facilities, respectively.
12 For the reference year 2000, water releases for PVC/EDC/VCM manufacturing facilities were
13 23.8 g I-TEQ_{DF} (22.6 g TEQ_{DF}-WHO₉₈), while water releases for chlor-alkali plants were 1.85 g
14 I-TEQ_{DF} (1.82 g TEQ_{DF}-WHO₉₈). More than 99% of the water releases from PVC/EDC/VCM
15 plants occurred at three facilities. More than 98% of the water releases from chlor-alkali plants
16 occurred at three facilities, with one facility accounting for over 58% of the water releases.
17 These emission estimates are assigned a medium confidence rating on the basis of the medium
18 rating given to the emission factor estimates.

19 20 **8.3.4.2. Wastewater Treatment Plant Solids**

21 The Vinyl Institute (1998) presented results for 14 samples collected in 1996 from nine
22 EDC/VCM/PVC manufacturing sites. Samples were collected from 4 of the 5 U.S. sites that
23 manufactured EDC, VCM, and PVC; 3 of the 7 U.S. sites that manufactured EDC and VCM but
24 not PVC; and 2 of the 21 sites that manufactured PVC but not EDC or VCM. On the basis of
25 1995 production data, the two PVC-only sites manufactured approximately 4.7% of the total
26 estimated U.S. and Canadian PVC resin produced. The sampled EDC/VCM and
27 EDC/VCM/PVC sites manufactured 56% of the total estimated 1995 U.S. EDC produced.
28 Samples from the PVC-only sites were taken from sites that manufactured suspension PVC resin
29 as well as sites that manufactured dispersion PVC resin. Samples taken from the EDC/VCM and
30 EDC/VCM/PVC sites were taken from sites that used direct and oxychlorination processes, fixed
31 and fluidized EDC reactor beds, low- and high-temperature direct chlorination, and air, oxygen,
32 and mixed air-oxygen feeds.

On the basis of the sample results, the Vinyl Institute determined that the results for facilities using different EDC reactor bed technologies (fluidized bed vs. fixed bed) appeared to differ significantly; therefore, they developed annual I-TEQ_{DF} emission estimates for three categories: PVC-only, EDC/VCM/PVC fixed-bed, and EDC/VCM/PVC fluidized-bed facilities. Nine U.S. sites use fixed-bed technology and six use fluidized-bed technology. Four of each type of facility were sampled by the Vinyl Institute. It is not possible, using the data presented in the Vinyl Institute (1998), to calculate emission factors for TEQ_{DF}-WHO₉₈. Because 1,2,3,7,8-PeCDD was detected in only 3 of 10 samples but OCDD and OCDF were detected in all samples, it is likely that the TEQ_{DF}-WHO₉₈ emission factors would not be significantly different from the I-TEQ_{DF} emission factors.

Results of the sampling are presented in Table 8-15. The MDLs for all congeners were less than 150 ng/kg and usually less than 10 ng/kg. CDDs/CDFs were detected in all samples. The ranges of TEQ concentrations (dry-weight basis) for the two PVC-only facilities were 1.1 to 2.6 ng I-TEQ_{DF}/kg (ND = 0) and 2.8 to 4.4 ng I-TEQ_{DF}/kg (ND = 1/2 MDL). On an emission-factor basis, the ranges were 1.7 to 46 µg I-TEQ_{DF}/1,000 metric tons of PVC produced (ND = 0) and 4.3 to 78 µg I-TEQ_{DF}/1,000 metric ton of PVC produced (ND = 1/2 DL). The range of TEQ concentrations for the samples from the EDC/VCM or EDC/VCM/PVC sites were 88 to 6,850 ng I-TEQ_{DF}/kg (ND = 0) and 93 to 6,850 ng I-TEQ_{DF}/kg (ND = 1/2 DL). On an emission-factor basis, the ranges were 28 to 4,000 µg I-TEQ_{DF}/1,000 metric tons of EDC (ND = 0) and 29 to 4,000 µg I-TEQ_{DF}/1,000 metric tons of EDC (ND = 1/2 DL).

The annual amounts of I-TEQ_{DF} generated in 1995 in each of the three facility categories were estimated by the Vinyl Institute as follows. First, total annual contributions at each sampled site were estimated by multiplying the I-TEQ_{DF} from the sample by the annual production of wastewater solids at that site. These annual site contributions of I-TEQ_{DF} were then summed for each of the three facility types and multiplied by the ratio of each category's total annual production of PVC or EDC to the sum of the annual production of the sampled sites in that category.

The Vinyl Institute (1998) combined these emission factors with 1995 industry production statistics to yield estimated amounts of I-TEQ_{DF} in wastewater treatment plant solids. For PVC-only facilities, estimated amounts are 0.069 g I-TEQ_{DF}/yr (ND = 0) and 0.12 g I-TEQ_{DF}/yr (ND = 1/2 DL), assuming an annual PVC production of 5,212,000 metric tons. For EDC/VCM/PVC fixed-bed facilities, the estimated amounts of TEQ are 1 g I-TEQ_{DF}/yr (ND = 0)

or ND = 1/2 DL), assuming an EDC annual production volume of 5,400,000 metric tons. For EDC/VCM/PVC fluidized-bed facilities, the estimated amount of TEQ is 11 g I-TEQ_{DF}/yr (ND = 0 or ND = 1/2 DL), assuming EDC annual production volume of 5,600,000 metric tons. Thus, total amounts of TEQ in wastewater treatment plant solids are estimated to have been 12.1 g I-TEQ_{DF} in 1995 (ND = 0 or ND = 1/2 DL).

According to the Vinyl Institute survey data, member companies dispose of wastewater solids by three methods: (1) RCRA hazardous waste landfilling (approximately 1% of industry total solids), (2) landfarming (approximately 6%), and (3) secure on-site landfilling (93%). Solids disposed of by methods 1 and 3 are assumed to be well controlled to prevent release into the general environment, whereas solids disposed of by landfarming are not as well controlled and could be released to the environment. Therefore, an estimated 0.73 g I-TEQ_{DF} (6% of 12.1 g I-TEQ_{DF}) can be considered as potentially released to the environment in 1995.

From the data validation studies presented in March 2004, only one facility (the Georgia Gulf facility in Plaquemine, LA) reported releases resulting from land farming activities in 2000 (CCC, 2004). The congener-specific profile is presented in Table 8-18. Releases to land from PVC/EDC/VCM facilities in 2000 were 1.36 g TEQ_{DF}-WHO₉₈ (1.45 g I-TEQ_{DF}).

These emission estimates are assigned a medium confidence rating on the basis of the medium rating given to the emission factor estimates.

8.3.4.3. Stack Gas Emissions

By grouping similarities of design and service, the Vinyl Institute (1998) subcategorized thermal destruction units at EDC/VCM and/or PVC manufacturing units into three categories: type A—vent gas incinerators at PVC-only resin plants, type B—vent gas thermal oxidizers at EDC/VCM plants, and type C—liquid-only and liquid/vent gas thermal oxidizers at EDC/VCM plants. Using an industry-wide survey, the Vinyl Institute identified 22 type A units at 11 facilities, 23 type B units at 10 facilities, and 17 type C units at 10 facilities. The Vinyl Institute gathered test data from 5 of the 22 type A units (3 facilities representing 7% of total U.S. and Canadian EDC/VCM/PVC production in 1995), 14 of the 23 type B units (8 facilities), and 13 of the 17 type C units (7 facilities). The sampled type B and C units represent 70% of total U.S. and Canadian EDC/VCM/PVC production in 1995.

Annual I-TEQ_{DF} emission estimates were generated by the Vinyl Institute by combining estimated emissions from tested units (i.e., based on measured stack gas results and plant-

specific activity data) with an estimate of emissions from untested units. The emissions from the untested units were estimated by multiplying the average emission factor for the tested units in the category (the most likely estimate) or by multiplying the average emission factor of the tested units with the highest emissions in each class (the upper-bound estimate) by the activity level for the untested units. It is not possible using the data presented in the Vinyl Institute report to calculate emission factors for TEQ_{DF}-WHO₉₈.

The Vinyl Institute estimates of most likely and upper-bound emissions during 1995 for these three categories are as follows:

| Category | Most likely emission estimate (g I-TEQ _{DF} /yr) | Upper-bound emission estimate (g I-TEQ _{DF} /yr) |
|---------------------------------|--|--|
| PVC-only incinerators | 0.0014 | 0.0019 |
| EDC/VCM liquid and liquid/vents | 3.7 | 7.2 |
| EDC/VCM vents for VCM only | 6.9 | 21.6 |

The Vinyl Institute (1998) also estimated emissions that may result from incineration of EDC/VCM/PVC wastes processed by off-site, third-party processing. Using the emission factors for liquid and liquid/vents developed in its study, the institute estimated that potential emissions to air from this source category would be 0.65 g I-TEQ_{DF}/yr (most-likely estimate) and 2.3 g I-TEQ_{DF}/yr (upper-bound estimate). Combining these third-party release estimates with those developed above yields a 1995 estimate of 11.2 g I-TEQ_{DF}/yr.

Data validation studies of the CCC indicate that eight PVC/EDC/VCM manufacturing facilities released 5.51 g I-TEQ_{DF} (5.46 g TEQ_{DF}-WHO₉₈) to air, while two chlor-alkali production plants reported releases to air of 0.08 g TEQ_{DF}-WHO₉₈ in 2000 (CCC, 2004). More than 85% of the air releases from PVC/EDC/VCM manufacturing facilities occurred at two facilities. Congener-specific profiles of the release estimates are provided in Tables 8-19 and 8-20. These emission estimates for 1995 and 2000 are assigned a medium confidence rating on the basis of the medium rating given to the emission factor estimates.

8.3.4.4. Products

The Vinyl Institute (1998) presented results for 22 samples from 14 of the 24 U.S. and Canadian facilities manufacturing suspension and mass PVC resins (13 pipe resins, 3 bottle resins, and 6 packaging resins). The results are summarized in Table 8-19. The 14 sampled sites

1 represent approximately 74% of estimated 1995 U.S. and Canadian suspension and mass PVC
2 resin production. CDDs/CDFs were detected in only one sample (0.043 ng I-TEQ_{DF}/kg,
3 assuming ND = 0). The overall mean TEQ concentrations were 0.002 ng I-TEQ_{DF}/kg (ND = 0)
4 and 0.7 ng I-TEQ_{DF}/kg (ND = 1/2 MDL). The MDLs were 2 ng/kg or less for all congeners in
5 all samples except for OCDD and OCDF, which had MDLs of 6 ng/kg or less.

6 The same study also presented results for six samples from four of the seven U.S.
7 facilities manufacturing dispersion PVC resins. CDDs/CDFs were detected in five of the
8 samples. The results are summarized in Table 8-21. In terms of production, the four sampled
9 sites represent approximately 61% of estimated 1995 U.S. dispersion PVC resin production. The
10 results ranged from not detected to 0.008 ng I-TEQ_{DF}/kg (overall mean = 0.001 ng I-TEQ_{DF}/kg,
11 assuming ND = 0, and 0.4 ng I-TEQ_{DF}/kg, assuming ND = 1/2 MDL). The MDLs were 2 ng/kg
12 or less for all congeners in all samples except OCDD and OCDF, which had MDLs of 4 ng/kg or
13 less.

14 Results were also presented for five samples from 5 of the 15 U.S. facilities
15 manufacturing EDC. The results are summarized in Table 8-21. In terms of production, the five
16 sampled sites represent approximately 71% of total U.S. estimated 1995 EDC produced.
17 CDDs/CDFs were detected in only one sample (0.03 ng I-TEQ_{DF}/kg). The overall mean TEQ
18 concentrations were 0.006 ng I-TEQ_{DF}/kg (ND = 0) and 0.21 ng I-TEQ_{DF}/kg (ND = 1/2 MDL).
19 The MDLs for all congeners were 1 ng/kg or less.

20 Using 1995 U.S. production data, 4.846 million metric tons of suspension and mass PVC,
21 0.367 million metric tons of dispersion PVC resins, and 1.362 million metric tons of EDC were
22 produced. Based on the average TEQ concentration observed, the Vinyl Institute estimated that
23 the total I-TEQ_{DF} contents of suspension/mass PVC resins, dispersion PVC resins, and EDC was
24 0.01 g, 0.004 g, and 0.008 g, respectively (ND = 0), and 3.39 g, 0.15 g, and 0.29 g, respectively
25 (ND = 1/2 MDL). Therefore, total I-TEQ_{DF} present in PVC in 1995 was estimated to be between
26 0.02 g (ND = 0) and 3.83 g (ND = 1/2 MDL). It is not possible using the data presented in the
27 Vinyl Institute report to calculate emission factors for TEQ_{DF}-WHO₉₈. However, because
28 neither 1,2,3,7,8-PeCDD nor OCDD was detected in any sample, the TEQ_{DF}-WHO₉₈ emission
29 factors would be very similar to the I-TEQ_{DF} emission factors.

30 In 2000, approximately 6.55 million metric tons of PVC and 9.91 million metric tons of
31 EDC were produced in North America (C&EN, 2002). In 1995, approximately 5.58 million
32 metric tons of PVC and 7.83 million metric tons of EDC were produced in North America

(C&EN, 2002). Of this total, approximately 94% of PVC production and approximately 17% of EDC production occurred in the United States and were sold as products. The breakdown of PVC manufacturing was as follows: 87 % of PVC produced was for suspension and mass PVC products and 7 % was for dispersion PVC resins. Assuming these percentages remained the same for 2000, it is estimated that approximately 5.69 million metric tons of suspension and mass PVC and 0.43 million metric tons of dispersion PVC resins were produced, and 1.72 million metric tons of EDC were produced. Applying the same average TEQ observed in the Vinyl Institute samples from 1998, EPA estimated the total I-TEQ_{DF} contents of suspension/mass PVC resins, dispersion PVC resins, and EDC produced in 2000 to be 0.01 g, 0.0004 g, and 0.01 g, respectively (ND = 0) and 3.99 g, 0.17 g, and 0.36 g, respectively (ND = 1/2 MDL). Therefore, total I-TEQ_{DF} present in PVC in 2000 was estimated to be between 0.02 g (ND = 0) and 4.52 g (ND = 1/2 MDL).

8.3.5. Other Aliphatic Chlorine Compounds

Aliphatic chlorine compounds are used as monomers in the production of plastics, as solvents and cleaning agents, and as precursors for chemical synthesis (Hutzinger and Fiedler, 1991a). These compounds are produced in large quantities. In 1992, 14.6 million metric tons of halogenated hydrocarbons were produced (U.S. International Trade Commission, 1946–1994). The production of 1,2-dichloroethane and vinyl chloride accounted for 82% of this total production. Highly chlorinated CDDs/CDFs (hexa- to octachlorinated congeners) have been found in nanograde-quality samples of 1,2-dichloroethane (55 ng/kg of OCDF in one of five samples), tetrachloroethene (47 ng/kg of OCDD in one of four samples), epichlorohydrin (88 ng/kg of CDDs and 33 ng/kg of CDFs in one of three samples), and hexachlorobutadiene (360 to 425 ng/kg of OCDF in two samples) obtained in Germany from the company Promochem (Hutzinger and Fiedler, 1991a; Heindl and Hutzinger, 1987). No CDDs/CDFs were detected in two samples of allyl chloride, three samples of 1,1,1-trichloroethane, and four samples of trichloroethylene (DL ranged from 5 to 20 ng/kg) (Heindl and Hutzinger, 1987). Because no more recent or additional data could be found in the literature to confirm these values for products manufactured or used in the United States, no national estimates of CDD/CDF emissions are made for the inventory.

EPA's Office of Water promulgated effluent limitations for facilities that manufacture chlorinated aliphatic chlorine compounds and discharge treated wastewater (40 CFR 414.70).

These effluent limitations do not specifically address CDDs or CDFs. The following chlorinated aliphatic compounds are regulated: 68 µg/L for 1,2-dichloroethane and 22 µg/L for tetrachloroethylene. Similarly, OSW promulgated restrictions on land disposal of wastes generated during the manufacture of many chlorinated aliphatics (40 CFR 268); however, these restrictions do not specifically regulate CDDs/CDFs.

8.3.6. Dyes, Pigments, and Printing Inks

Several researchers analyzed various dyes, pigments, and printing inks obtained in Canada and Germany for the presence of CDDs/CDFs (Williams et al., 1992; Hutzinger and Fiedler, 1991a; Santl et al., 1994). The following subsections discuss the findings of those studies.

8.3.6.1. Dioxazine Dyes and Pigments

Williams et al. (1992) analyzed the CDD/CDF content in dioxazine dyes and pigments available in Canada. As shown in Table 8-20, OCDD and OCDF concentrations in the ng/kg range and HpCDD, HxCDD, and PeCDD concentrations in the µg/kg range were found in Direct Blue 106 dye (three samples), Direct Blue 108 dye (one sample), and Violet 23 pigments (six samples) (Williams et al., 1992). These dioxazine pigments are derived from chloranil, which has been found to contain high levels of CDDs/CDFs and has been suggested as the source of contamination among these dyes (Christmann et al., 1989a; Williams et al., 1992; U.S. EPA, 1992b). In May 1990, EPA received test results showing that chloranil was heavily contaminated with dioxins; levels as high as 2,903 µg TEQ_{DF}-WHO₉₈/kg (3,065 µg I-TEQ_{DF}/kg) were measured in samples from four importers (mean value of 1,388 µg TEQ_{DF}-WHO₉₈/kg [1,754 µg I-TEQ_{DF}/kg]) (U.S. EPA, 1992b; Remmers et al., 1992). (See Section 8.3.7 for analytical results.)

In the early 1990s, EPA learned that I-TEQ_{DF} levels in chloranil could be reduced by more than two orders of magnitude (to less than 20 µg/kg) through manufacturing feedstock and process changes. EPA's Office of Pollution Prevention and Toxics subsequently began efforts to complete an industry-wide switch from the use of contaminated chloranil to low-dioxin chloranil. Although chloranil is not manufactured in the United States, significant quantities are imported. As of May 1992, EPA had negotiated agreements with all chloranil importers and domestic dye/pigment manufacturers known to EPA that used chloranil in their products to

switch to low-dioxin chloranil. In May 1993, when U.S. stocks of chloranil with high levels of CDDs/CDFs had been depleted, EPA proposed a SNUR under Section 5 of TSCA that would require industry to notify EPA at least 90 days prior to the manufacture, import, or processing, for any use, of chloranil containing CDDs/CDFs at a concentration greater than 20 $\mu\text{g I-TEQ}_{\text{DF}}/\text{kg}$ (Federal Register, 1993a; U.S. EPA, 1993c).

In 1983, approximately 36,500 kg of chloranil were imported (U.S. ITC, 1984). The U.S. International Trade Commission has not published quantitative import data for chloranil since 1984. If it is assumed that this import volume reflects actual usage of chloranil in the United States during 1987 and that the CDD/CDF contamination level was 1,388 $\mu\text{g TEQ}_{\text{DF-WHO}_{98}}/\text{kg}$ (1,754 $\mu\text{g I-TEQ}_{\text{DF}}/\text{kg}$), then the maximum release into the environment via processing wastes and finished products was 50.6 g $\text{TEQ}_{\text{DF-WHO}_{98}}$ (64 g I-TEQ_{DF}). If it is assumed that the import volume in 1995 was also 36,500 kg but that the imported chloranil contained 10 $\mu\text{g I-TEQ}_{\text{DF}}/\text{kg}$ on average, then the total potential annual TEQ release associated with chloranil in 1995 was 50.6 g $\text{TEQ}_{\text{DF-WHO}_{98}}$ (64 g I-TEQ_{DF}).

In 1986, EPA promulgated the Inventory Update Rule (IUR) that requires the partial updating of the Toxic Substances Control Act (TSCA) Chemical Inventory database. Every four years, chemical manufacturers and importers of chemicals listed on the TSCA inventory that produce at one plant site or import at production volume levels of 10,000 or more pounds must report the range of chemical production or import. According to information entered in the TSCA database, 10,000 to 500,000 pounds (4,540 to 227,000 kg) of chloranil were imported in 1994 and 2000 (<http://www.epa.gov/opptintr/iur/iur02/search03.htm>). Assuming the imported chloranil contained the same concentration of dioxin as the 1995 estimate above (10 $\mu\text{g I-TEQ}_{\text{DF}}/\text{kg}$), the total potential annual TEQ release associated with chloranil in 2000 was 0.05 to 2.27 g $\text{I-TEQ}_{\text{DF-WHO}_{98}}$ (mean of 1.16 g I-TEQ_{DF}).

8.3.6.2. Phthalocyanine Dyes and Printing Inks

Hutzinger and Fiedler (1991a) found CDDs/CDFs (tetra-, penta-, and hexachlorinated congeners) in the $\mu\text{g}/\text{kg}$ range in a sample of a Ni-phthalocyanine dye. No CDDs/CDFs were detected (DL of 0.1 to 0.5 $\mu\text{g}/\text{kg}$) in two samples of Cu-phthalocyanine dyes and in one Co-phthalocyanine dye (Hutzinger and Fiedler, 1991a).

Santl et al. (1994) reported the results of analyses of four printing inks obtained from a supplier in Germany. Two of the inks are used for rotogravure printing and two are used for

offset printing. The results of the analyses are presented in Table 8-21. The TEQ_{DF}-WHO₉₈ content of the inks ranged from 17.7 to 87.2 ng/kg (15 to 88.6 ng/kg on an I-TEQ_{DF} basis). Primarily non-2,3,7,8-substituted congeners were found. The identities of the dyes and pigments in these inks were not reported.

Although EPA provided an estimate of potential environmental release based on limited information of contaminant levels of CDDs/CDFs in the product, the estimate is still too uncertain to include in the quantitative inventory of sources. It is currently not known if the dioxin contamination in the product actually results in a release to the open and circulating environment.

8.3.7. TSCA Dioxin/Furan Test Rule

Citing evidence that halogenated dioxins and furans may be formed as by-products during chemical manufacturing processes (Versar, 1985), EPA issued a rule under Section 4 of TSCA that requires chemical manufacturers and importers to test for the presence of CDDs/CDFs and BDDs/BDFs in certain commercial organic chemicals (Federal Register, 1987c). The rule listed 12 manufactured or imported chemicals that required testing and 20 chemicals not currently manufactured or imported that would require testing if manufacture or importation resumed. These chemicals are listed in Table 8-24. The specific dioxin and furan congeners that require quantitation and the target limits of quantitation (LOQs) that are specified in the rule are listed in Table 8-25. Under Section 8(a) of TSCA, the final rule also required that chemical manufacturers submit data on manufacturing processes and reaction conditions for chemicals produced using any of the 28 precursor chemicals listed in Table 8-26. The rule stated that subsequent to this data-gathering effort, testing may be proposed for additional chemicals if any of the manufacturing conditions used favored the production of dioxins and furans.

Twenty-three sampling and analytical protocols and test data for 10 of the 12 chemicals that required testing were submitted to EPA (U.S. EPA, 2003f). Manufacture or import of two substances (tetrabromobisphenol-A-bis-2,3-dibromopropylether and tetrabromobisphenol-A-diacrylate) have stopped since the test rule was promulgated. (All data and reports in the EPA TSCA docket are available for public review and inspection at EPA Headquarters in Washington, DC.)

Table 8-27 presents the results of analytical testing for CDDs/CDFs for the chemicals that have data available in the TSCA docket. Five of these 10 chemicals contained CDDs/CDFs.

Positive results were obtained for 2,3,5,6-tetrachloro-2,5-cyclohexadiene-1,4-dione (chloranil), pentabromodiphenyloxide, octabromodiphenyloxide, decabromodiphenyloxide, and 1,2-Bis(tribromophenoxy)-ethane. Table 8-28 presents the quantitative analytical results for four submitted chloranil samples, as well as the results of an EPA analysis of a sample of carbazole violet, which is manufactured from chloranil.

Although testing conducted under this test rule for 2,4,6-tribromophenol indicated no halogenated dioxins or furans above the LOQs, Thoma and Hutzinger (1989) reported detecting BDDs and BDFs in a technical-grade sample of this substance. Total TBDD, TBDF, and PeBDF were found at 84 µg/kg, 12 µg/kg, and 1 µg/kg, respectively. No hexa-, hepta-, or octa-BDFs were detected. Thoma and Hutzinger (1989) also analyzed analytical-grade samples of two other brominated flame retardants, pentabromophenol and tetrabromophthalic anhydride; no BDDs or BDFs were detected (DLs not reported).

8.3.8. Halogenated Pesticides and FIFRA Pesticides Data Call-In

In the late 1970s and early 1980s, attention began to focus on pesticides as potential sources of CDDs/CDFs in the environment. Up to that time, CDD/CDF levels were not regulated in end-use pesticide products. However, some of the active ingredients in pesticides, particularly chlorinated phenols and their derivatives, were known or suspected to be contaminated with CDDs/CDFs. During the 1980s and 1990s, EPA took several actions to investigate and control CDD/CDF contamination of pesticides.

Actions to regulate 2,4,5-T and Silvex. In 1983, EPA cancelled the sale of Silvex and 2,4,5-T for all uses (Federal Register, 1987e). Earlier, in 1979, EPA had ordered emergency suspension of the forestry, rights-of-way, and pasture uses of 2,4,5-T. Emergency suspensions of the forestry, rights-of-way, pasture, home and garden, commercial/ornamental turf, and aquatic weed control/ditch bank uses of Silvex were also ordered (Federal Register, 1979; Plimmer, 1980). The home and garden, commercial/ornamental turf, and aquatic weed control/ditch bank uses of 2,4,5-T had been suspended in 1970.

Actions to regulate PCP. In 1984, EPA issued a notice of intent to cancel registrations of pesticide products containing PCP (including its salts) for all wood preservative uses (Federal Register, 1984). This notice specified modifications to the terms and conditions of product registrations that were required in order to avoid cancellation of the products. In response to this notice, several trade associations and registrants requested administrative hearings to challenge

1 EPA's determinations. After carefully considering the comments and alternatives suggested
2 during the prehearing stage of the administrative proceedings, EPA concluded that certain
3 changes to the 1984 notice were appropriate. These changes, finalized in 1986 (Federal Register,
4 1986), included the following: (a) all wood preservative uses of PCP and its salts were classified
5 as "restricted use" only by certified applicators, (b) specific worker protection measures were
6 required, (c) limits were placed on the HxCDD content of PCP, and (d) label restrictions for
7 home and farm uses of PCP prohibited its application indoors and to wood intended for interior
8 use (with a few exceptions) as well as its application in a manner that might result in direct
9 exposure of domestic animals or livestock or in the contamination of food, feed, or drinking and
10 irrigation water.

11 EPA subsequently amended its Notice on the wood preservative uses to establish reliable
12 and enforceable methods for implementing certified limits for HxCDD and 2,3,7,8-TCDD in
13 registered wood preservative pesticide products (Federal Register, 1987a). Levels of 2,3,7,8-
14 TCDD were not allowed to exceed 1 ppb in any product, and after February 2, 1989, any
15 manufacturing-use PCP released for shipment could not contain HxCDD levels that exceeded an
16 average of 2 ppm over a monthly release or a batch level of 4 ppm (a gradually phased-in
17 requirement). On January 21, 1987, EPA prohibited the registration of PCP and its salts for most
18 nonwood uses (Federal Register, 1987b). EPA deferred action on several uses (uses in
19 pulp/paper mills, oil wells, and cooling towers) pending receipt of additional exposure, use, and
20 ecological effects data. On January 8, 1993, EPA issued a press advisory stating that its special
21 review of these deferred nonwood uses was being terminated because all of these uses had been
22 either voluntarily cancelled by the registrants or cancelled by EPA for failure of the registrants to
23 pay the required annual maintenance fees (U.S. EPA, 1993f).

24 PCP was one of the most widely used biocides in the United States prior to the regulatory
25 actions to cancel and restrict certain of its wood and nonwood preservative uses. PCP was
26 registered for use as a herbicide, defoliant, mossicide, and mushroom house biocide. It also
27 found use as a biocide in pulp-paper mills, oil wells, and cooling towers. These latter three uses
28 were terminated on or before 1993 (U.S. EPA, 1993f). However, the major use (greater than
29 80% of consumption) of PCP was and continues to be wood preservation.

30 The production of PCP for wood preserving began on an experimental basis in the 1930s.
31 In 1947, nearly 3,200 metric tons of PCP were reported to have been used in the United States by
32 the commercial wood preserving industry. Use in this industry steadily increased through the

1 mid-1970s (American Wood Preservers Institute, 1977). Although domestic consumption
2 volumes are not available for all years, it is estimated, on the basis of historical
3 production/export data for PCP reported in Mannsville (1983), that 90 to 95% of production
4 volume has typically been consumed domestically rather than exported. A reasonable estimate
5 of average annual domestic PCP consumption during the period 1970 to 1995 is about 400,000
6 metric tons. This estimate assumes an average annual consumption rate of 20,000 metric tons/yr
7 during the 1970s, 15,000 metric tons/yr during the 1980s, and 10,000 metric tons/yr during the
8 1990s.

9 Table 8-8 presents a compilation of published data on the CDD/CDF content of
10 technical-grade PCP. The only samples that have been analyzed for all dioxin-like CDDs/CDFs
11 were manufactured in the mid to late 1980s. Figure 8-4 presents these data in graphical form. It
12 is evident from the figures that the predominant congener groups are OCDD, OCDF, HpCDF,
13 and HpCDD, and the dominant 2,3,7,8-substituted congeners are OCDD, 1,2,3,4,6,7,8-HpCDD,
14 and OCDF. Waddell et al. (1995) tested analytical-grade PCP (from Aldrich Chemical Co.) for
15 CDD/CDF content and found the same congener profile; however, the CDD/CDF levels were
16 three to four orders of magnitude lower. Table 8-9 presents a similar compilation of published
17 data on the CDD/CDF content of PCP-Na. The table shows the same patterns of dominant
18 congeners and congener groups reported for PCP.

19 Samples of technical PCP manufactured during the mid to late 1980s contained about 1.7
20 mg TEQ_{DF-WHO98}/kg (3 mg I-TEQ/kg), based on the data presented in Table 8-8. No published
21 reports could be located that present the results of any congener-specific analyses of PCP
22 manufactured since the late 1980s. However, monthly measurements of CDD/CDF congener
23 group concentrations in technical PCP manufactured for use in the United States have been
24 reported to EPA from 1987 to the present (KMG-Bernuth, 1997; Pentachlorophenol Task Force,
25 1997; U.S. EPA, 1999a). The average congener group concentrations reported to EPA for the
26 years 1988 (i.e., one year after EPA regulations were imposed limiting HxCDD and 2,3,7,8-
27 TCDD concentrations in PCP) to 1999 are presented in Table 8-8. In general, the average
28 congener group concentrations during the period 1988 to 1999 are lower by factors of 2 to 4 than
29 those observed in the mid to late 1980s' full congener analysis samples. If it is assumed that the
30 toxic CDD/CDF congeners have also been reduced by similar factors, then the TEQ content of
31 PCP manufactured since 1988 is about 0.6 mg TEQ_{DF-WHO98}/kg (1 mg I-TEQ/kg).

1 An estimated 12,000 metric tons of PCP were used for wood preservation in the United
2 States in 1987 (WHO, 1991). An estimated 8,400 metric tons were used in 1994 (American
3 Wood Preservers Institute, 1995); for purposes of this report, it is assumed that an identical
4 amount was used in 1995. In 1999, approximately 7,710 metric tons of PCP were produced
5 annually in the United States (Council of Great Lakes Industries, 1999); for purposes of this
6 report, it is assumed that an identical amount was produced in 2000. Assuming that 95% of the
7 production volume was consumed domestically (Mannsville, 1983), and that all of the PCP
8 produced in 2000 was used for wood preservation, approximately 7,325 metric tons of PCP was
9 used in the United States for wood preservation. Combining these activity level estimates with
10 the TEQ concentration estimates presented above indicates that 20,000 ug TEQ_{DF}-WHO₉₈
11 (36,000 ug I-TEQ_{DF}), 4,800 ug TEQ_{DF}-WHO₉₈ (8,400 ug I-TEQ_{DF}), and 4,175 ug TEQ_{DF}-
12 WHO₉₈ (7,325 ug I-TEQ_{DF}) were incorporated into PCP-treated wood products in 1987, 1995,
13 and 2000, respectively. These amounts in PCP products are not considered an environmental
14 release and therefore are not included in the inventory. As discussed below, there is some
15 evidence that releases could occur, but no consistent estimation approach could be found.

16 Although the estimates of the mass of TEQ in treated wood are fairly certain, no studies
17 are available that provide measured CDD/CDF release rate data from which a reliable estimate
18 can be made of the amount of CDDs/CDFs that have or will volatilize or leach from treated
19 wood. Several recent field studies, discussed in the following paragraphs, demonstrate that
20 CDDs/CDFs do apparently leach into soil from PCP-treated wood, but the studies do not provide
21 release rate data. No studies were located that provide any measured CDD/CDF volatilization
22 rates from PCP-treated wood. Although CDDs/CDFs have very low vapor pressures, they are
23 not bound to, nor do they react with, the wood in any way that would preclude volatilization.
24 Several studies, discussed below, have attempted to estimate potential CDD/CDF volatilization
25 releases using conservative assumptions or modeling approaches, but these estimates span many
26 orders of magnitude.

27 Gurprasad et al. (1995) analyzed three PCP-treated utility poles and their surrounding
28 surface soils for penta- through octa-CDD content. All three poles showed significant levels of
29 HxCDD (0.29 to 0.47 mg/kg), HpCDD (4.69 to 6.63 mg/kg), and OCDD (27.9 to 42.1 mg/kg),
30 but no PeCDD. Surface soils collected 2 cm from the poles also had detectable levels of
31 HxCDD, HpCDD, and OCDD; however, no consistent pattern was found between the CDD
32 concentrations in the poles and those in the adjacent soils. The soil concentrations did, however,

show the same relative congener group pattern observed in the wood. CDD concentrations in soils obtained 20 cm from the poles were an order of magnitude less than those measured at 2 cm. Soils 26 m from the poles showed nondetect values or values close to the DL of 0.01 to 0.02 mg/kg.

In a study of the leaching of PCP from 31 utility poles, the Electric Power Research Institute (EPRI, 1995) found similar patterns of PCP distribution in soils surrounding poles as those found by Gurprasad et al. (1995) for CDDs. PCP concentrations decreased by as much as two orders of magnitude between 7.5 cm from the poles and 20 cm from the poles, with an average decrease of slightly more than one order of magnitude over this distance. EPRI (1995) also found no obvious trend between PCP concentration in the wood (eight poles analyzed) and the age of the poles (4 to 11 years) or the PCP concentration in the surface soil. On the basis of their results and those of EPRI (1995), Gurprasad et al. concluded that CDDs probably leach from PCP-treated utility poles with the PCP/oil carrier and travel in the soil in a similar manner.

Wan (1995) and Wan and Van Oostdam (1995) measured CDD/CDF concentrations in waters and sediments from ditches surrounding utility poles and railroad ties and demonstrated that chlorophenol-treated wood could serve as a source of CDD/CDFs to the aquatic environment. Ten samples were collected at each of six utility pole sites and five railroad tie sites 1 to 2 days after major rainfall events and then were composited into one sample per site prior to analyses. Total CDDs (mean value of 76.7 mg/kg) and total CDFs (mean value of 18.7 mg/kg) detected in chlorophenol/creosote-treated utility poles were about 6 to 8 times greater, respectively, than the CDD and CDF concentrations detected in chlorophenol/creosote-treated railroad ties. Total CDDs found in water from railway ditches without utility poles (i.e., only treated railroad ties were present) were approximately 20 times higher than the background level found in farm ditch water. Total CDDs in railway ditches with utility poles were 4,300 times higher than the background levels. Water from railway ditches without utility poles contained total CDF levels 13 times higher than background levels, whereas water in ditches adjacent to poles were 8,500 times higher than background levels. Total CDDs in ditch sediments adjacent to, and 4 m downstream of, utility poles were about 5,900 and 2,200 times higher, respectively, than background levels; total CDFs for the same sites were about 8,100 and 1,700 times higher, respectively, than background levels. Total CDDs found in ditch sediments of railway and ditch sediments adjacent to utility poles were about 5 and 700 times higher, respectively, than background levels; while total CDFs were about 9 and 1,800 times higher, respectively, than background levels. Both CDDs and CDFs were found in utility ditch sediments 4 m downstream of treated power poles, but at levels of 200 and 400 times, respectively, lower than those found

adjacent to poles, indicating that they were transported from point sources of contamination. The corresponding values for CDFs were 5,400 and 8,000 times, respectively, higher in concentration.

Bremmer et al. (1994) estimated an annual release of 15 to 125 g of I-TEQ_{DF} from PCP-treated wood in the Netherlands. The lower estimate was based on three basic assumptions: (1) the half-life of PCP in treated wood is 15 years (according to industry sources), (2) the half-life of CDDs/CDFs in treated wood is 10 times that of PCP (i.e., 150 years) because of the lower vapor pressures of CDDs/CDFs relative to PCP, and (3) the typical CDD/CDF concentration in PCP has been 3000 µg/kg. The higher estimate was based on an assumed half-life of PCP in wood of 15 years and the results of an indoor air study by Papke et al. (1989) conducted at several kindergartens where PCP-treated wood had been used. Although Papke et al. found no clear correlation between indoor air concentrations of CDD/CDF and PCP across the range of CDD/CDF concentrations observed in the 20-plus samples (2.6 to 427 pg CDD/CDF/m³), there did appear to be a positive correlation at the sites with more elevated CDD/CDF concentrations. Bremmer et al. (1994) reported that the average ratio of PCP to I-TEQ_{DF} air concentrations at these elevated sites to be $1:5 \times 10^{-6}$ (or about the same ratio as the concentration of I-TEQ_{DF} in technical PCP). The results of the Papke et al. (1989) study imply that CDDs/CDFs may be released from PCP-treated wood at the same rate as PCP rather than at a rate 10 times slower.

Rappe (1995) used the emission factor approach developed by Bremmer et al. (1994) and an assumed U.S. usage volume of PCP over the past 50 years (0.5 million metric tons) to estimate that as much as 10.5 kg of I-TEQ_{DF} could volatilize from PCP-treated wood in the United States annually. Eitzer and Hites (1987) derived a dramatically different estimate of CDD/CDF volatilization from PCP-treated wood in the United States: 3 kg/yr of total CDD/CDF (or 66 g of I-TEQ_{DF} per year, assuming an I-TEQ_{DF} content in PCP of 3 mg/kg). Eitzer and Hites based their estimate on an assumption that 0.1% of the PCP produced annually enters the atmosphere and that the CDD/CDF contaminants present in the PCP (assumed to be 130 mg/kg) are released to the atmosphere at the same rate as the PCP (i.e., 0.1%). The basis for the first assumption by Eitzer and Hites is not clear because EPA, which was cited as the source of the 0.1% emission factor (U.S. EPA, 1980), does not appear to address volatilization of PCP from in-service treated wood. The report does, however, estimate that most PCP in treated wood leaches relatively rapidly from the wood, presumably to land, within a period of 12 years.

1 Eduljee and Dyke (1996) and Douben et al. (1995) estimated that 0.8 g of I-TEQ_{DF} is
2 released to the air annually from PCP-treated wood in the United Kingdom. This estimate was
3 based on the assumed emission of 0.1% of the CDD/CDF present in PCP-treated wood during
4 the first year of the service life of the wood that was assumed by Eitzer and Hites (1987). No
5 emission was assumed for subsequent years of use of the treated wood.

6 The California Air Resources Board (Chinkin et al., 1987) generated estimates of
7 CDD/CDF volatilization releases at wood treatment facilities from bundles of treated wood that
8 remain on site for 1 month prior to shipment. An “adapted” version of a model developed by
9 McCord (1981) was used for estimating volatile releases from a constantly filling lagoon. The
10 model is primarily driven by chemical-specific vapor pressures and air diffusivity coefficients.
11 Chinkin et al. did not provide all model input parameter values used to generate the emission
12 estimates. However, running the model with typical dimensions for treated poles yields an I-
13 TEQ_{DF} emission rate on the order of 6E-12 g/yr-pole, an extremely low number (170 billion
14 poles would together emit 1 g TEQ/yr).

15 **Actions to identify other pesticides containing CDDs/CDFs.** In addition to cancelling
16 some pesticide registrations and establishing product standards, EPA’s Office of Pesticide
17 Programs (OPP) issued two DCIs in 1987. Pesticide manufacturers are required to register their
18 products with EPA in order to market them commercially in the United States. Through the
19 registration process, mandated by FIFRA, EPA can require that the manufacturer of each active
20 ingredient generate a wide variety of scientific data through several mechanisms. The most
21 common process is the five-phase reregistration process, with which the manufacturers (i.e.,
22 registrants) of older pesticide products must comply. In most registration activities, registrants
23 must generate data under a series of strict testing guidelines, 40 CFR 158—Pesticide Assessment
24 Guidelines (U.S. EPA, 1988b). EPA can also require additional data from registrants, when
25 necessary, through various mechanisms, including the DCI process.

26 The purpose of the first DCI, dated June and October 1987, “Data Call-In Notice for
27 Product Chemistry Relating to Potential Formation of Halogenated Dibenzo-*p*-dioxin or
28 Dibenzofuran Contaminants in Certain Active Ingredients,” was to identify, using an analysis of
29 raw materials and process chemistry, those pesticides that might contain halogenated dibenzo-*p*-
30 dioxin (HDD) and halogenated dibenzofuran (HDF) contaminants. The 93 pesticides (76
31 pesticide active ingredients) to which the DCI applied, along with their corresponding
32 Shaughnessey and Chemical Abstract code numbers, are presented in Table 8-29. (The

1 Shaughnessey code is an internal EPA tracking system. It is of interest because chemicals with
2 similar code numbers are similar in chemical nature [e.g., salts, esters, and acid forms of 2,4-D].)

3 All registrants supporting registrations for these chemicals were subject to the
4 requirements of the DCI unless their product qualified for a Generic Data Exemption (i.e., a
5 registrant exclusively used a FIFRA-registered pesticide product[s] as the source[s] of the active
6 ingredient[s] identified in Table 8-29 in formulating their product[s]). Registrants whose
7 products did not meet the Generic Data Exemption were required to submit the types of data
8 listed below to enable EPA to assess the potential for formation of tetra- through hepta-HDD or
9 HDF contaminants during manufacture. Registrants, however, had the option to voluntarily
10 cancel their product or “reformulate to remove an active ingredient” to avoid having to comply
11 with the DCI.

- 12
13 • Product identity and disclosure of ingredients. EPA required submittal of a
14 Confidential Statement of Formula (CSF), based on the requirements specified in 40
15 CFR 158.108 and 40 CFR 158.120, Subdivision D: Product Chemistry. Registrants
16 who had previously submitted still-current CSFs were not required to resubmit this
17 information.
- 18
19 • Description of beginning materials and manufacturing process. Under the
20 requirements mandated by 40 CFR 158.120, Subdivision D, EPA required submittal
21 of a manufacturing process description for each step of the manufacturing process,
22 including specification of the range of acceptable conditions of temperature, pressure,
23 or pH at each step.
- 24
25 • Discussion of the formation of impurities. Under the requirements mandated by 40
26 CFR 158.120, Subdivision D, EPA required submittal of a detailed discussion and
27 assessment of the possible formation of HDDs and HDFs.

28
29 The second DCI, dated June and October 1987, “Data Call-In for Analytical Chemistry
30 Data on Polyhalogenated Dibenzo-*p*-Dioxins/Dibenzofurans (HDDs and HDFs),” was issued for
31 68 pesticides (16 pesticide active ingredients) suspected to be contaminated by CDDs/CDFs (see
32 Table 8-28). All registrants supporting registrations for these pesticides were subject to the
33 requirements of this DCI unless the product qualified for various exemptions or waivers.
34 Pesticides covered by the second DCI were strongly suspected by EPA to contain detectable
35 levels of CDDs/CDFs.

1 Under the second DCI, registrants whose products did not qualify for an exemption or
2 waiver were required to generate and submit the following types of data in addition to the data
3 requirements of the first DCI:
4

- 5 • Quantitative method for measuring CDDs or CDFs. Registrants were required to
6 develop an analytical method for measuring the HDD/HDF content of their products.
7 The DCI established a regimen for defining the precision of the analytical method.
8 Target LOQs were established in the DCI for specific CDD/CDF congeners (see
9 Table 8-23).
- 10 • Certification of limits of CDDs or CDFs. Registrants were required to submit a
11 “Certification of Limits” in accordance with 40 CFR 158.110 and 40 CFR 158.120,
12 Subdivision D. Analytical results were required that met the guidelines described
13 above.
14

15
16 Registrants could select one of two options to comply with the second DCI. The first
17 option was to submit relevant existing data, develop new data, or share the cost to develop new
18 data with other registrants. The second option was to alleviate the DCI requirements through
19 several exemption processes, including a Generic Data Exemption, voluntary cancellation,
20 reformulation to remove the active ingredient of concern, an assertion that the data requirements
21 did not apply, or the application or award of a low-volume, minor-use waiver.

22 The data contained in CSFs, as well as any other data generated under 40 CFR 158.120,
23 Subdivision D, are typically considered confidential business information (CBI) under the
24 guidelines prescribed in FIFRA because they usually contain information regarding proprietary
25 manufacturing processes. In general, all analytical results submitted to EPA in response to both
26 DCIs are considered CBI and cannot be released by EPA into the public domain. Summaries
27 based on the trends identified in that data, as well as data made public by EPA, are summarized
28 below.

29 The two DCIs included 161 pesticides. Of these, 92 are no longer supported by
30 registrants. Following evaluation of the process chemistry submissions required under the DCIs,
31 OPP determined that formation of CDDs/CDFs was not likely during the manufacture of 43 of
32 the remaining 69 pesticides; thus, analysis of samples of these 43 pesticides was not required by
33 OPP. Evaluation of process chemistry data is ongoing at OPP for an additional 7 pesticides.
34 Tables 8-29 and 8-30 indicate which pesticides are no longer supported, those for which OPP

determined that CDD/CDF formation is unlikely, and those for which process chemistry data or analytical testing results are under review (U.S. EPA, 1995f).

OPP required that analysis of production samples be performed on the remaining 19 pesticides (see Table 8-31). The status of the analytical data generation/evaluation to date is summarized as follows: (a) no detection of CDDs/CDFs above the LOQs in registrant submissions for 13 active ingredients, (b) detection of CDDs/CDFs above the LOQs for 2,4-D acid (two submissions) and 2,4-D 2-ethyl hexyl acetate (one submission), and (c) ongoing data generation or evaluation for four pesticides.

Table 8-32 presents a summary of results obtained by EPA for CDDs/CDFs in eight technical 2,4-D herbicides; these data were extracted from program files in OPP. Because some of these files contained CBI, the data in this table were reviewed by OPP staff to ensure that no CBI was being disclosed (Funk, 1996). Figure 8-5 presents a congener profile for 2,4-D based on the average congener concentrations reported in Table 8-33.

Schechter et al. (1997) reported the results of analyses of samples of 2,4-D manufactured in Europe, Russia, and the United States (see Table 8-33). The total TEQ concentrations measured in the European and Russian samples were similar to those measured in the EPA DCI samples; however, the levels reported by Schechter et al. for U.S. samples were significantly lower. Similarly, Masunaga et al. (2001) reported the analyses of two agrochemical formulations containing 2,4-D manufactured in Japan (Table 8-31). The total TEQ concentration measured in one of the samples was similar to what Schechter et al. (1997) reported for the U.S. samples; no TEQ was detected in the other sample.

As discussed in Section 12.2.1, an estimated 28,100 metric tons of 2,4-D were used in the United States in 2000, making it one of the top 10 pesticides in terms of quantity used (EPA proprietary data). The pesticide 2,4-D is the only product judged to have the potential for environmental release through its agricultural use. However, no estimate of environmental release can be made for the year 2000. Since 1995, the chemical manufacturers of 2,4-D have been undertaking voluntary actions to significantly reduce the dioxin content of the product. No information is available on the level of dioxin contamination, if any, that may have been present in 2,4-D in the year 2000. An estimated 26,300 and 30,400 metric tons were used during 1995 and 1987, respectively (U.S. EPA, 1997e, 1988c). On the basis of the average CDD/CDF congener concentrations in 2,4-D presented in Table 8-33 (not including OCDD and OCDF), the

corresponding TEQ_{DF}-WHO₉₈ concentration is 1.1 µg/kg (0.7 µg I-TEQ_{DF}/kg). Combining this TEQ concentration with the activity level estimates for 1995 and 1987 indicates that 28.9 g TEQ_{DF}-WHO₉₈ (18.4 g I-TEQ_{DF}) were released in 1995 and 33.4 g TEQ_{DF}-WHO₉₈ (21.3 g I-TEQ_{DF}) in 1987. The release estimates for 1987 and 1995 are assigned a high confidence rating, indicating high confidence in both the production and the emission factor estimates. Because no estimate can be made for 2000, it is rated as Category E.

8.4. OTHER CHEMICAL MANUFACTURING AND PROCESSING SOURCES

8.4.1. Municipal Wastewater Treatment Plants

8.4.1.1. Sources

CDDs/CDFs have been measured in nearly all sewage sludges tested, although the concentrations and, to some extent, the congener profiles and patterns differ widely. Potential sources of the CDDs/CDFs include microbial formation (discussed in Chapter 9), runoff to sewers from lands or urban surfaces contaminated by product uses or deposition of previous emissions to air (discussed in Section 12.2.1), household wastewater, industrial wastewater, chlorination operations within the wastewater treatment facility, or a combination of all the above (Rappe, 1992a; Rappe et al., 1994; Horstmann et al., 1992; Sewart et al., 1995; Cramer et al., 1995; Horstmann and McLachlan, 1995).

The major source(s) for a given publicly owned treatment works (POTW) is likely to be site specific, particularly in industrialized areas. For example, Rieger and Ballschmiter (1992) traced the origin of CDDs/CDFs found in municipal sewage sludge in Ulm, Germany, to metal manufacturing and urban sources. The characteristics of both sources were similar and suggested generation via thermal processing. However, in a series of recent studies, Horstmann et al. (1992, 1993a, b) and Horstmann and McLachlan (1994a, b, 1995) demonstrated that wastewater generated by laundering and bathing could be the major source at many, if not all, POTWs that serve primarily residential populations. Although runoff from streets during precipitation events, particularly from streets with high traffic density, was reported by these researchers as contributing measurably, the total contribution of TEQ from household wastewater was eight times greater than that from surface runoff at the study city.

Horstmann et al. (1992) provided initial evidence that household wastewater could be a significant source. Horstmann et al. (1993a) measured CDD/CDF levels in the effluent from four different loads of laundry from two different domestic washing machines. The

1 concentrations of total CDDs/CDFs in the four samples ranged from 3,900 to 7,100 pg/L and
2 were very similar in congener profile, with OCDD being the dominant congener, followed by the
3 hepta- and hexa-CDDs. Because of the similar concentrations and congener profiles found, the
4 authors concluded that the presence of CDDs/CDFs in washing machine wastewater is
5 widespread. A simple mass balance performed using the results (Horstmann and McLachlan,
6 1994a) showed that the CDDs/CDFs found in the four washing machine wastewater samples
7 could account for 27 to 94% of the total CDDs/CDFs measured in the sludge of the local
8 wastewater treatment plant.

9 Horstmann et al. (1993a) performed additional experiments that showed that detergents,
10 commonly used bleaching agents, and the washing cycle process itself were not responsible for
11 the observed CDDs/CDFs. To determine whether the textile fabric or fabric finishing processes
12 could account for the observed CDDs/CDFs, Horstmann et al. (1993b), Horstmann and
13 McLachlan (1994a, b), and Klasmeier and McLachlan (1995) analyzed the CDDs/CDFs content
14 of raw cotton cloth, white synthetic materials, and more than 100 new textile finished products.
15 Low concentrations were found in most products (less than 50 ng/kg of total CDDs/CDFs), but a
16 small percentage contained high concentrations, up to 290 µg/kg of total CDDs/CDFs. On the
17 basis of the concentrations and patterns found, the authors concluded that neither unfinished new
18 fabrics nor common cotton finishing processes could explain the CDD/CDF levels found in
19 wastewater; rather, the use of CDD-/CDF-containing textile dyes and pigments and the use in
20 some developing countries of PCP to treat unfinished cotton appeared to be the sources of the
21 detected CDDs/CDFs.

22 Horstmann and McLachlan (1994a, b, 1995) reported the results of additional
23 experiments showing that the small percentage of clothing items with high CDD/CDF levels
24 could be responsible for the quantity of CDDs/CDFs observed in household wastewater and
25 sewage sludge. They demonstrated that the CDDs/CDFs can be gradually removed from the
26 fabric during washing; they can be transferred to the skin, subsequently transferred back to other
27 textiles, and then washed out, or they can be transferred to other textiles during washing and then
28 removed during subsequent washing.

29 30 **8.4.1.2. Releases to Water**

1 **8.4.1.2.1. Emissions data.** The presence of CDDs/CDFs in sewage sludge suggests that
2 CDDs/CDFs may also be present in the wastewater effluent discharges of POTWs; however, few
3 studies reporting the results of effluent analyses for CDDs/CDFs have been published.

4 Rappe et al. (1989a) tested the effluent from two Swedish POTWs for all 2,3,7,8-
5 substituted CDD/CDF congeners. OCDD was detected in the effluents from both facilities at
6 concentrations ranging from 14 to 39 pg/L. Rappe et al. detected 1,2,3,4,6,7,8-HpCDD and
7 1,2,3,4,6,7,8-HpCDF in the effluent of one facility at concentrations of 2.8 and 2 pg/L,
8 respectively. No 2,3,7,8-substituted tetra-, penta-, and hexa-CDDs or CDFs were detected (DLs
9 of 0.2 to 20 pg/L).

10 Ho and Clement (1990) reported the results of sampling during the late 1980s of 37
11 POTWs in Ontario, Canada, for each of the five CDD/CDF congener groups with four to eight
12 chlorines. The sampled facilities included 27 secondary treatment facilities, seven primary
13 treatment facilities, one tertiary plant, and two lagoons. The facilities accounted for about 73%
14 of the sewage discharged by POTWs in Ontario. No CDDs/CDFs were detected (DL in low
15 ng/L range) in the effluents from the lagoons and the tertiary treatment facility. Only OCDD and
16 TCDF were detected in the effluents from the primary treatment facilities (two and one effluent
17 samples, respectively). HpCDD, OCDD, TCDF, and OCDF were detected in the effluents from
18 the secondary treatment facilities (detected in four or fewer samples at levels ranging from 0.1 to
19 11 ng/L).

20 Gobran et al. (1995) analyzed the raw sewage and final effluent of an Ontario, Canada,
21 wastewater treatment plant for CDD/CDF congeners over a 5-day period. Although HpCDD,
22 OCDD, HpCDF, and OCDF were detected in the raw sewage (12 to 2,300 pg/L), no
23 CDDs/CDFs were detected in the final effluent at congener-specific DLs ranging from 3 to 20
24 pg/L.

25 The California Regional Water Quality Control Board (CRWQCB, 1996) reported the
26 results of effluent testing at nine POTWs in the San Francisco area. A total of 30 samples were
27 collected between 1992 and 1995 and 1 to 6 samples were analyzed for each POTW. As
28 summarized in Table 8-32, the overall mean TEQ concentration is 0.27 pg TEQ_{DF}-WHO₉₈/L
29 (0.29 pg I-TEQ_{DF}/L). With the exception of OCDD, most 2,3,7,8-substituted CDD/CDF
30 congeners were seldom detected.

31 Rappe et al. (1998) analyzed effluent samples from 17 POTWs in Mississippi, 10 of
32 which receive input from industrial facilities. Treatment processes at the facilities include the

1 use of one or more of the following: lagoons, activated sludge, aerated digestion, wetlands,
2 oxidative ditch, and trickling filter. Additionally, 12 of the facilities use chlorine gas in the
3 treatment process. The wastewater flows at the facilities range from 0.11 to 39.75 million liters
4 per day; however, wastewater flow rates were not known for two facilities. Table 8-33 presents
5 the concentrations of dioxins measured in the effluent samples for each facility and total TEQ
6 emission factors. Concentrations were only congener-specific for 2,3,7,8-TCDD; 2,3,7,8-TCDF;
7 1,2,3,7,8-PeCDD; 2,3,4,7,8-PeCDF; OCDD; and OCDF. Also provided were concentrations for
8 total HxCDD and total HpCDD. The total TEQ concentrations reported by Rappe et al.
9 (assuming ND = 1/2 DL) ranged from 0.274 to 3.84 pg I-TEQ_{DF}/L (average of 0.86 pg/I-
10 TEQ_{DF}/L). Because concentrations for all congeners were not provided, emission factors could
11 not be calculated in TEQ_{DF}-WHO₉₈.

12 The CRWQCB (1996) data were collected to provide representative effluent
13 concentrations for the San Francisco area. These data cannot be considered to be representative
14 of CDD/CDF effluent concentrations at the 16,000-plus POTWs nationwide. Therefore, the data
15 can be used only to generate a preliminary estimate of the potential mass of CDD/CDF TEQ that
16 may be released annually by U.S. POTWs.

17
18 **8.4.1.2.2. Activity level information.** Based on the results of the 1996 and 2000 Clean Water
19 Needs Surveys, estimates show that approximately 122 billion liters and 148 billion liters of
20 wastewater were treated daily by POTWs in the United States in 1996 and 2000, respectively
21 (U.S. EPA, 1997c, 2004).

22 Wastewater treatment data were not available for the year 1987, however, an estimate
23 was developed using the population of the United States as a surrogate. In 2000, the population
24 of the United States was approximately 281 million people. Using the estimate of water treated
25 daily by POTWs in 2000, approximately 527 L/person of wastewater were treated daily by
26 POTWs. In 1990, the population of the United States was approximately 249 million people.
27 Assuming the population did not change drastically between 1987 and 1990, and assuming that
28 the daily domestic wastewater treatment per person remained constant between 1987 and 2000,
29 EPA estimates that approximately 131 billion liters of wastewater were treated daily at POTWs
30 in 1987.

1 **8.4.1.2.3. Emission Estimates.** By multiplying the amount of wastewater treated by 365 days/yr
2 and by the “overall mean” TEQ concentrations reported by CRWQCB (i.e., 0.27 pg TEQ_{DF}-
3 WHO₉₈/L and 0.29 pg I-TEQ_{DF}/L), yields annual TEQ release estimates of 12.9 g TEQ_{DF}-
4 WHO₉₈ (13.9 g of I-TEQ_{DF}), 12 g TEQ_{DF}-WHO₉₈ (13 g of I-TEQ_{DF}), and 14.6 g TEQ_{DF}-WHO₉₈
5 (15.7 g I-TEQ_{DF}) for 1987, 1995, and 2000, respectively. These estimates should be regarded as
6 preliminary indications of possible emissions from this source.

8 **8.4.1.3. Sewage Sludge Land Disposal**

9 Sewage sludge is the solid, semi-solid, or liquid residue generated during the treatment of
10 wastewater. During wastewater treatment, nutrients, pathogens, inorganic compounds (metals
11 and trace elements), and organic compounds (CDDs/CDFs, PCBs, and surfactants) from the
12 incoming wastewater are partitioned to the resulting sewage sludge (National Research Council,
13 2002). The sludge is either disposed of through methods such as incineration or landfill/surface
14 disposal or beneficially used through methods such as land application.

15 Sewage sludge that is applied to land is referred to as biosolids. In order to be applied to
16 the land, the biosolids must be treated to meet land application regulatory requirements (Federal
17 Register, 1993b). With respect to land application, biosolids are often used for crop production,
18 gardening, forestry, turf growth, and landscaping. Some other uses include strip mine and gravel
19 pit reclamation and wetland restoration. Land application of biosolids is beneficial because it
20 improves the physical and chemical properties of the soil needed for plant growth, it reduces the
21 need for other disposal methods, and it reduces or eliminates the need for commercial fertilizers.
22 Commercial fertilizers often have higher nutrient contents than do biosolids; therefore, the
23 application of biosolids to land in lieu of commercial fertilizers may reduce the impacts of high
24 levels of excess nutrients entering the environment (U.S. EPA, 1999e).

25
26 **8.4.1.3.1. Emissions data.** EPA conducted the National Sewage Sludge Survey in 1988 and
27 1989 to obtain national data on sewage sludge quality and management. As part of this survey,
28 EPA analyzed sludges from 174 POTWs that employed at least secondary wastewater treatment
29 for more than 400 analytes, including CDDs/CDFs. Although sludges from only 16% of the
30 POTWs had detectable levels of 2,3,7,8-TCDD, all sludges had detectable levels of at least one
31 CDD/CDF congener (U.S. EPA, 1996a). I-TEQ_{DF} concentrations as high as 1,820 ng/kg dry
32 weight were measured. The congener-specific results of the survey are presented in Table 8-36.

1 If all nondetect values found in the study are assumed to be zero, then the mean and median I-
2 TEQ_{DF} concentrations of the sludges from the 174 POTWs are 50 and 11.2 ng/kg (dry-weight
3 basis), respectively. If the nondetect values are set equal to the DL, then the mean and median I-
4 TEQ_{DF} concentrations are 86 and 50.4 ng/kg, respectively (U.S. EPA, 1996a; Rubin and White,
5 1992).

6 Green et al. (1995) and Cramer et al. (1995) reported the results of analyses of 99
7 samples of sewage sludge collected from wastewater treatment plants across the United States
8 during the summer of 1994 as part of the 1994/1995 Association of Metropolitan Sewerage
9 Agencies (AMSA) survey. These data are summarized in Table 8-37. To calculate average
10 results in units of TEQ, Green et al. averaged the results from all samples collected from the
11 same facility to ensure that the results were not biased toward the concentrations found at
12 facilities from which more than one sample was collected. Also, eight samples were excluded
13 from the calculation of the overall TEQ averages because it was unclear as to whether they were
14 duplicate samples from other POTWs. POTW average TEQ concentrations were calculated for
15 74 POTWs. If all nondetect values are assumed to be zero, then the overall study mean and
16 median I-TEQ_{DF} concentrations are 47.7 and 33.4 ng I-TEQ_{DF}/kg (dry weight basis), respectively
17 (standard deviation of 44.7 ng I-TEQ_{DF}/kg). The corresponding mean and median TEQ_{DF}-
18 WHO₉₈ concentrations are 36.3 and 25.5 ng/kg, respectively (standard deviation, 38.6).

19 The mean and median results reported by Green et al. (1995) and Cramer et al. (1995) are
20 very similar in terms of total TEQ to those reported by EPA for samples collected five years
21 earlier (U.S. EPA, 1996a; Rubin and White, 1992). The predominant congeners in both data sets
22 are the octa- and hepta-CDDs and CDFs. Although not present at high concentrations, 2,3,7,8-
23 TCDF was commonly detected.

24 In addition to effluents, Rappe et al. (1998) also analyzed the levels of CDDs and CDFs
25 in municipal sewage sludge from the 17 POTWs in Mississippi. Table 8-38 presents the
26 concentrations of dioxins measured in the sewage sludge samples and total TEQ emission factors
27 reported by Rappe et al. Concentrations were only congener specific for 2,3,7,8-TCDD; 2,3,7,8-
28 TCDF; 1,2,3,7,8-PeCDD; 2,3,4,7,8-PeCDF; OCDD; and OCDF. Also provided were
29 concentrations for total HxCDD and total HpCDD. The TEQ emission factors (assuming ND =
30 1/2 DL) reported by Rappe et al. ranged from 2.26 to 1,270 ng I-TEQ_{DF}/kg. The predominant
31 congeners in all samples were the octa- and hepta-CDDs. The sludge with the highest
32 concentrations of octa- and hepta-CDDs was from the Picayune POTW, which receives

1 industrial inputs, including effluents from wood treatment facilities that likely contain PCP. In
2 general, the sludge with the lowest TEQ values were from the facilities that do not receive
3 effluent from industrial facilities. Additionally, the samples with the two lowest TEQ values
4 were from facilities that do not use free chlorine as a disinfectant.

5 In 1999, sewage sludge samples from a POTW in Ohio were collected and analyzed for
6 CDDs/CDFs (U.S. EPA, 2000f). The facility, which accepts both domestic and industrial
7 wastewater, employs secondary wastewater technology. Assuming nondetects are zero, the
8 mean TEQ emission factor is 21.9 ng TEQ_{DF}-WHO₉₈/kg (dry-weight basis). These results are
9 presented in Table 8-39.

10 In 2000 and 2001, AMSA conducted another survey of dioxin-like compounds in sewage
11 sludge (Alvarado et al., 2001). A total of 200 sewage sludge samples were collected from 171
12 POTWs located in 31 states. Assuming nondetects are zero, TEQ emission factors range from
13 0.08 to 3,578.61 ng TEQ_{DF}-WHO₉₈/kg. The mean and median TEQ emission factors are 34.5
14 and 11.79 ng TEQ_{DF}-WHO₉₈/kg, respectively.

15 EPA conducted another National Sewage Sludge Survey to characterize the dioxin and
16 dioxin-like equivalence levels in biosolids produced by 6857 POTWs operating in the United
17 States in 2001 (U.S. EPA, 2002a). Samples were collected from 94 POTWs using secondary or
18 higher treatment practices. All facilities had been sampled previously as part of the 1988/1989
19 National Sewage Sludge Survey. The overall mean and median TEQ_{DF}-WHO₉₈ concentrations
20 were 75 and 15 ng/kg, respectively. However, when the data were weighted using the daily
21 influent wastewater flow rates (i.e., the number of facilities with wastewater flow rate
22 >100 Mg/day, >10 but ≤100 Mg/day, >1 but ≤10 Mg/day, and ≤1 Mg/day), the overall mean and
23 median TEQ_{DF}-WHO₉₈ concentrations were 21.7 and 15.5 ng/kg, respectively. These data are
24 summarized in Table 8-40.

25 The CDD/CDF concentrations and congener group patterns observed in the U.S. surveys
26 are similar to those reported for sewage sludges in several other Western countries. Stuart et al.
27 (1993) reported mean CDD/CDF concentrations of 23.3 ng I-TEQ_{DF}/kg (dry weight) for three
28 sludges from rural areas, 42.3 ng I-TEQ_{DF}/kg for six sludges from light industry/domestic areas,
29 and 52.8 ng I-TEQ_{DF}/kg for six sludges from industrial/domestic areas collected during 1991–
30 1992 in England and Wales. Näf et al. (1990) reported concentrations ranging from 31 to 40 ng
31 I-TEQ_{DF}/kg (dry weight) in primary and digested sludges collected from the POTW in
32 Stockholm, Sweden, during 1989. Gobran et al. (1995) reported an average concentration of

1 15.7 ng I-TEQ_{DF}/kg in anaerobically digested sludges from an industrial/domestic POTW in
2 Ontario, Canada. In all three studies, the congener group concentrations increased with
3 increasing degrees of chlorination, with OCDD the dominant congener. Figure 8-6 presents
4 congener profiles, using the mean concentrations reported by Green et al. (1995).

5 Because the mean I-TEQ_{DF} concentration values reported in the 1988/1989 sewage
6 sludge survey (U.S. EPA, 1996a) and the 1995 survey (Green et al., 1995; Cramer et al., 1995)
7 were very similar, the estimated amounts of TEQs that may have been present in sewage sludge
8 and released to the environment in 1987 and 1995 were assumed to be the same. These values
9 were estimated using the average (49 ng I-TEQ_{DF}/kg) of the mean I-TEQ_{DF} concentration values
10 (ND = DLs) reported by U.S. EPA (1996a) (50 ng I-TEQ_{DF}/kg) and by Green et al. (1995) and
11 Cramer et al. (1995) (36.3 ng TEQ_{DF}-WHO₉₈/kg [47.7 ng I-TEQ_{DF}/kg]). Therefore, the overall
12 average mean emission factor for the reference years 1987 and 1995 is 36.3 ng TEQ_{DF}-
13 WHO₉₈/kg (48.9 ng I-TEQ_{DF}/kg). The emission factor of 21.7 ng TEQ_{DF}-WHO₉₈/kg, as
14 calculated from the 2001 survey, appears to be the most reasonable TEQ emission factor
15 estimate for reference year 2000 because this estimate is nationally weighted on the basis of
16 wastewater flow rates of POTWs operating in the United States in 2001.

17
18 **8.4.1.3.2. Activity level information.** According to the results of its 1988/1989 National
19 Sewage Sludge Survey, EPA estimated that approximately 5.4 million dry metric tons of sewage
20 sludge were generated in 1989 (Federal Register, 1993b). EPA also used the results of the 1984
21 to 1996 Clean Water Needs Surveys to estimate that 6.3 million dry metric tons of sewage sludge
22 were generated in 1998. Because estimates for reference years 1987 and 1995 are not available,
23 the 1989 and 1998 activity level estimates are used for 1987 and 1995, respectively. Tables 8-41
24 and 8-42 list the volumes, by use and disposal practices, of sludge disposed of annually for
25 reference years 1987 and 1995.

26 U.S. EPA (1999) estimated that 6.6 million dry metric tons of sewage sludge would be
27 generated in 2000. Table 8-43 lists the volumes, by use and disposal practices, of sludge
28 disposed of annually for reference year 2000. Similarly, the National Research Council (NRC)
29 (NRC, 2002) analyzed the amount of biosolids being applied to land in 2002. Citing 2001 data
30 (unpublished) from the Wisconsin Department of Natural Resources, NRC estimated that
31 approximately 8,650 of the 16,000 POTWs operating in the United States generated sewage
32 sludge requiring use or disposal. Using data from 37 states, an estimated 5,900 of these sewage

1 sludge generators either land applied or publicly distributed more than 3.4 million dry tons of
2 biosolids annually. The volume of biosolids, by use and disposal practices, is presented in Table
3 8-44. The volume of biosolids and their distribution among the various categories estimated by
4 the NRC are very close to those estimated by the EPA.

5
6 **8.4.1.3.3. Emission estimates.** The annual potential releases of CDDs/CDFs are determined by
7 multiplying the mean total TEQ concentrations by the sludge volumes generated. The results for
8 reference years 1987, 1995, and 2000 are reported in Table 8-41, 8-42, and 8-43, respectively.
9 For reference year 1987, the total annual potential release from nonincinerated sludges was 151 g
10 $\text{TEQ}_{\text{DF-WHO}_{98}}$. Of this amount, 2.6 g $\text{TEQ}_{\text{DF-WHO}_{98}}$ (3.5 g I- TEQ_{DF}) entered commerce as a
11 product for distribution and marketing and 76.6 g $\text{TEQ}_{\text{DF-WHO}_{98}}$ (103 g I- TEQ_{DF}) was applied
12 to land. The remaining 71.8 g $\text{TEQ}_{\text{DF-WHO}_{98}}$ did not result in an environmental release because
13 it was sent to RCRA Subtitle D landfills or disposal sites. For reference year 1995, the total
14 annual potential release from nonincinerated sludges was 178 g $\text{TEQ}_{\text{DF-WHO}_{98}}$. Of this amount,
15 3 g $\text{TEQ}_{\text{DF-WHO}_{98}}$ (4 g I- TEQ_{DF}) entered commerce as a product for distribution and
16 marketing, and 116.1 g $\text{TEQ}_{\text{DF-WHO}_{98}}$ (156.5 g I- TEQ_{DF}) was applied to land. The remaining
17 58.9 g $\text{TEQ}_{\text{DF-WHO}_{98}}$ did not result in an environmental release because it was sent to RCRA
18 Subtitle D landfills or disposal sites. For the year 2000, the total annual release of
19 nonincinerated sludges was 111 g $\text{TEQ}_{\text{DF-WHO}_{98}}$. Of this amount, 1.9 g $\text{TEQ}_{\text{DF-WHO}_{98}}$ (1.9 g
20 I- TEQ_{DF}) entered commerce as a product for distribution and marketing, and 78.2 g $\text{TEQ}_{\text{DF-}}$
21 WHO_{98} (78.2 g I- TEQ_{DF}) was applied to land. The remaining 30.9 g $\text{TEQ}_{\text{DF-WHO}_{98}}$ did not
22 result in an environmental release because it was sent to RCRA Subtitle D landfills or disposal
23 sites.

24 These release estimates are assigned a high confidence rating for both the production and
25 emission factor estimates. The high rating was based on the judgment that the 174 facilities
26 tested as part of the 1988/1989 National Sewage Sludge Survey by EPA (U.S. EPA, 1996a), the
27 74 facilities tested as part of the 1994/1995 AMSA Survey (Green et al., 1995 and Cramer et al.,
28 1995), and the 94 facilities tested as part of the 2001 National Sewage Sludge Survey (EPA
29 2002) were reasonably representative of the variability in POTW technologies and sewage
30 characteristics nationwide.

31 32 **8.4.2. Drinking Water Treatment Plants**

1 There is no strong evidence that chlorination of water for drinking purposes results in the
2 formation of CDDs/CDFs. Few surveys of CDD/CDF content in finished drinking water have
3 been conducted. Those that have been published have only rarely reported the presence of any
4 CDDs/CDFs, even at low pg/L DLs, and in those cases, CDDs/CDFs were also present in the
5 untreated water.

6 Rappe et al. (1989b) reported the formation of tetra- through octa-CDFs when tap water
7 and double-distilled water were chlorinated using chlorine gas. The CDF levels found in the
8 single samples of tap water and double-distilled water were 35 and 7 pg I-TEQ_{DF}/L, respectively.
9 No CDDs were detected at DLs ranging from 1 to 5 pg/L. However, the water samples were
10 chlorinated at a dosage rate of 300 mg/L, which is considerably higher (by one to two orders of
11 magnitude) than the range of dosage rates typically used to disinfect drinking water. The authors
12 hypothesized that the CDFs or their precursors were present in chlorine gas.

13 Rappe et al. (1990a) analyzed a 1,500 L sample of drinking water from a municipal
14 drinking water treatment plant in Sweden. Although the untreated water was not analyzed, a
15 sludge sample from the same facility was analyzed. The large sample volume enabled DLs on
16 the order of 0.001 pg/L. The TEQ content of the water and sludge was 0.0029 pg I-TEQ_{DF}/L and
17 1.4 ng/kg, respectively. The congener patterns of the drinking water and sludge sample were
18 very similar, suggesting that the CDDs/CDFs detected in the finished water were present in the
19 untreated water.

20 21 **8.4.3. Soaps and Detergents**

22 As discussed in Section 8.4.1, CDDs/CDFs were detected in nearly all sewage sludges
23 tested, whether the sludges were obtained from industrialized areas or from rural areas. Because
24 of the ubiquitous presence of CDDs/CDFs in sewage sludge, several studies have been
25 conducted to determine their source(s). A logical category of products to test, because of their
26 widespread use, is detergents, particularly those that contain or release chlorine during use (i.e.,
27 hypochlorite-containing and dichloroisocyanuric acid-containing detergents). The results of
28 studies conducted to date, summarized below, indicate that CDDs/CDFs are not formed during
29 use of chlorine-free detergents, chlorine-containing or chlorine-releasing detergents, or chlorine
30 bleach during household bleaching operations.

31 Sweden's Office of Nature Conservancy (1991) reported that the results of a preliminary
32 study conducted at one household indicated that CDDs/CDFs may be formed during use of

dichloroisocyanurate-containing dishwasher detergents. A more extensive main study with multiple runs was then conducted using standardized food, dishes, cutlery, and other household items. Testing of laundry washing and fabric bleaching and actual testing of the CDD/CDF content of detergents was also performed. The study examined (1) hypochlorite- and dichloroisocyanurate-containing dishwasher detergents, (2) sodium hypochlorite-based bleach (4.4% NaOCl) in various combinations with and without laundry detergent, and (3) sodium hypochlorite-based bleach, used at a high enough concentration to effect bleaching of a pair of imported blue jeans.

CDDs/CDFs were not detected in either the chlorine-free detergent or the detergent with hypochlorite; 0.6 pg TEQ/g were detected in the detergent containing dichloroisocyanurate. The results of all dishwasher and laundry washing machine tests showed very low levels of CDDs/CDFs, often nondetected values. There was no significant difference between the controls and the test samples; in fact, the control samples had a higher TEQ content than did some of the test samples. The drainwater from the dishwasher tests contained <1 to <3 pg I-TEQ_{DF}/L (the water-only control sample contained <2.8 pg I-TEQ_{DF}/L). The CDD/CDF content of the laundry drainwater samples ranged from <1.1 to <4.6 pg I-TEQ_{DF}/L (the water-only control sample contained <4.4 pg I-TEQ_{DF}/L).

Thus, under the study's test conditions, CDDs/CDFs were not formed during dishwashing or laundry washing or during bleaching with hypochlorite-containing bleach. No definitive reason could be found for the difference in results between the preliminary study and the main study for dishwashing with dichloroisocyanurate-containing detergents. The authors of the study suggested that differences in the foods used and the prewashing procedures employed in the two studies were the likely causes of the variation in the results.

Rappe et al. (1990c) analyzed a sample of a Swedish commercial soft soap, a sample of tall oil, and a sample of tall resin for CDD/CDF content. Tall oil and tall resin, by-products of the pulping industry, are the starting materials for the production of soft, liquid soap. Crude tall oil, collected after the Kraft pulping process, is distilled under reduced pressure at temperatures of up to 280 to 290 °C, yielding tall oil and tall resin. The measured TEQ content of the liquid soap was found to be 0.647 ng TEQ_{DF}-WHO₉₈/L (0.447 ng I-TEQ_{DF}/L). PeCDDs were the dominant congener group, followed by HpCDDs, HxCDDs, PeCDFs, and OCDD, with some tetra-CDFs and CDDs also present. The TEQ contents of the tall oil (12 ng TEQ_{DF}-WHO₉₈/kg [9.4 ng I-TEQ_{DF}/kg]) and tall resin (196 ng TEQ_{DF}-WHO₉₈/kg [200 ng I-TEF_{DF}/kg]) were

significantly higher than the level found in the liquid soap. The tall oil contained primarily tetra- and penta-CDDs and CDFs, whereas the tall resin contained primarily HpCDDs, HxCDDs, and OCDD. The investigators compared the congener patterns of the three samples and noted that although the absolute values for the tetra- and penta-CDDs and CDFs differed among the tall oil, tall resin, and liquid soap samples, the same congeners were present. The congener patterns for the more-highly chlorinated congeners were very similar. Table 8-44 presents the results of the study.

In 1987, 118 million L of liquid household soaps were shipped in the United States (U.S. DOC, 1990b); shipment quantity data are not available in the 1992 U.S. Economic Census (U.S. DOC, 1996). Because only one sample of liquid soap has been analyzed for CDD/CDF content (Rappe et al., 1990c), no estimate of environmental release can be made.

8.4.4. Textile Manufacturing and Dry Cleaning

As discussed in Section 8.4.1, CDDs/CDFs have been detected in almost all sewage sludges tested, whether they were obtained from industrialized areas or rural areas. To determine whether textile fabric or fabric finishing processes could account for the observed CDDs/CDFs, several studies were conducted in Germany. These studies, summarized in the following paragraphs, indicate that some finished textile products do contain detectable levels of CDDs/CDFs and that they can be released from the textile during laundering or dry cleaning; however, textile finishing processes are typically not sources of CDD/CDF formation. Rather, the use of CDD/CDF-containing dyes and pigments and the use in some countries of PCP to treat unfinished cotton appear to be the sources of the detected CDDs/CDFs.

Horstmann et al. (1993b) analyzed the CDD/CDF content of eight different raw (unfinished) cotton cloths containing fiber from different countries and five different white synthetic materials (acetate, viscose, bleached polyester, polyamide, and polyacrylic). The maximum concentrations found in the textile fabrics were 30 ng/kg in the cotton products and 45 ng/kg in the synthetic materials. Also, a cotton finishing scheme was developed that subjected one of the cotton materials to a series of 16 typical cotton finishing processes; one sample was analyzed following each step. The fabric finishing processes showing the greatest effect on CDD/CDF concentration were the application of an indanthrene dye and the “wash and wear” finishing process, which together resulted in a CDD/CDF concentration of about 100 ng/kg. On the basis of the concentrations found, the authors concluded that neither unfinished new fabrics

nor common cotton finishing processes could explain the CDD/CDF levels found in laundry wastewater.

Fuchs et al. (1990) reported that the dry-cleaning solvent redistillation residues collected from 12 commercial and industrial dry-cleaning operations contained considerable amounts of CDDs/CDFs. The reported I-TEQ_{DF} content ranged from 131 to 2,834 ng/kg, with the dominant congeners being OCDD and HpCDD. Towara et al. (1992) demonstrated that neither the use of chlorine-free solvents nor variation of the dry-cleaning process parameters lowered the CDD/CDF content of the residues.

Umlauf et al. (1993) conducted a study to characterize the mass balance of CDDs/CDFs in the dry-cleaning process. The soiled clothes (containing 16 pg total CDDs/CDFs per kg) accounted for 99.996% of the CDD/CDF input. Input of CDDs/CDFs from indoor air containing 0.194 pg/m³ accounted for the remainder (0.004%). The dry-cleaning process removed 82.435% of the CDDs/CDFs in the soiled clothing. Most of the input CDDs/CDFs (82.264%) were found in the solvent distillation residues. Air emissions (at 0.041 pg/m³) accounted for 0.0008% of the total input, which was less than the input from indoor air. The fluff (at a concentration of 36 ng/kg) accounted for 0.1697%, and water effluent (at a concentration of 0.07 pg/L) accounted for 0.0000054%.

Horstmann and McLachlan (1994a, b, 1995) analyzed 35 new textile samples (primarily cotton products) obtained in Germany for CDDs/CDFs. Low levels were found in most cases (total CDD/CDF less than 50 ng/kg). The dominant congeners were OCDD and HpCDD. However, several colored T-shirts from a number of clothing producers had extremely high levels, with concentrations up to 290,000 ng/kg. Because the concentrations in identical T-shirts purchased at the same store varied by up to a factor of 20, the authors concluded that the source of CDDs/CDFs was not a textile finishing process, because a process source would have resulted in a more consistent level of contamination. Klasmeier and McLachlan (1995) subsequently analyzed 68 new textile products obtained in Germany for OCDD and OCDF. Most samples had nondetectable levels (42 samples <60 ng/kg). Only four samples had levels exceeding 500 ng/kg.

Horstmann and McLachlan (1994a, b) reported finding two different congener group patterns in the more contaminated of the 35 textile products. One pattern agreed with the congener pattern for PCP reported by Hagenmaier and Brunner (1987), whereas the other pattern was similar to that reported by Remmers et al. (1992) for chloranil-based dyes. The authors

1 hypothesized that the use of PCP to preserve cotton, particularly when it is randomly strewn on
2 bales of cotton as a preservative during sea transport, was the likely source of the high levels
3 occasionally observed. Although the use of PCP for nonwood uses was prohibited in the United
4 States in 1987 (see Section 8.3.8), PCP is still used in developing countries, especially to
5 preserve cotton during sea transport (Horstmann and McLachlan, 1994a).

6 Horstmann and McLachlan (1994a, b) conducted additional experiments that
7 demonstrated that the small percentage of clothing items with high CDD/CDF levels could be
8 responsible for the quantity of CDDs/CDFs observed in household wastewater (see Section
9 8.4.1.1).

Table 8-1. CDD/CDF concentrations in pulp and paper mill bleached pulp, wastewater sludge, and wastewater effluent (circa 1988)

| Congener/congener group | Bleached pulp | | | Wastewater sludge | | | Wastewater effluent | | |
|---|----------------|--------------------|-----------------------------|-------------------|------------------|----------------------------|---------------------|-------------------|----------------------------|
| | Median (ng/kg) | Range (ng/kg) | No. of detects (10 samples) | Median (ng/kg) | Range (ng/kg) | No. of detects (9 samples) | Median (pg/L) | Range (pg/L) | No. of detects (9 samples) |
| 2,3,7,8-TCDD | 6.4 | 0.4 to 124 | 10 | 63 | ND(6.3) to 180 | 8 | 42 | ND(11) to 98 | 8 |
| 1,2,3,7,8-PeCDD | ND(0.3) | ND(0.1) to 1.4 | 2 | ND(2.5) | ND(1.4) to 28 | 1 | ND(9.6) | ND(2.8) to ND(25) | 0 |
| 1,2,3,4,7,8-HxCDD | ND(0.4) | ND(0.2) to 0.4 | 1 | ND(3.1) | ND(1.5) to 40 | 1 | ND(12) | ND(6.6) to ND(12) | 0 |
| 1,2,3,6,7,8-HxCDD | ND(0.5) | ND(0.2) to 1.6 | 2 | ND(3.2) | ND(1.7) to 95 | 1 | ND(12) | ND(6.6) to ND(24) | 0 |
| 1,2,3,7,8,9-HxCDD | ND(0.5) | ND(0.2) to 0.5 | 1 | ND(3.9) | ND(1.7) to 80 | 1 | ND(12) | ND(6.6) to ND(23) | 0 |
| 1,2,3,4,6,7,8-HpCDD | 3.3 | 2.3 to 8.4 | 10 | 37 | 18 to 490 | 9 | 170 | 77 to 270 | 9 |
| OCDD | 46 | 28 to 81 | 10 | 698 | 263 to 1,780 | 9 | 3,000 | 1,000 to 4,600 | 9 |
| 2,3,7,8-TCDF | 18 | 1.4 to 716 | 10 | 233 | 13 to 1150 | 9 | 120 | 12 to 840 | 9 |
| 1,2,3,7,8-PeCDF | ND(0.7) | ND(0.1) to 3.9 | 4 | 6.2 | ND(1.2) to 22 | 6 | ND(7.2) | ND(2.2) to 36 | 2 |
| 2,3,4,7,8-PeCDF | ND(0.2) | ND(0.1) to 4.7 | 3 | 4.7 | ND(0.9) to 38 | 6 | ND(6.3) | ND(2.2) to 33 | 2 |
| 1,2,3,4,7,8-HxCDF | ND(0.3) | ND(0.2) to ND(0.6) | 0 | ND(2.5) | ND(0.9) to 31 | 2 | ND(8.4) | ND(4.8) to ND(15) | 0 |
| 1,2,3,6,7,8-HxCDF | ND(0.3) | ND(0.1) to ND(0.4) | 0 | ND(1.4) | ND(0.9) to 33 | 1 | ND(7.1) | ND(4.8) to ND(15) | 0 |
| 1,2,3,7,8,9-HxCDF | ND(0.3) | ND(0.1) to ND(0.4) | 0 | ND(1.7) | ND(0.9) to ND(4) | 0 | ND(6.2) | ND(2.5) to ND(15) | 0 |
| 2,3,4,6,7,8-HxCDF | ND(0.3) | ND(0.2) to ND(0.4) | 0 | ND(1.7) | ND(0.9) to 34 | 1 | ND(8.2) | ND(4.8) to ND(15) | 0 |
| 1,2,3,4,6,7,8-HpCDF | ND(0.6) | ND(0.1) to 0.8 | 3 | 6.6 | ND(3.6) to 70 | 7 | ND(23) | ND(13) to 44 | 3 |
| 1,2,3,4,7,8,9-HpCDF | ND(0.6) | ND(0.1) to ND(2.1) | 0 | ND(1.6) | ND(1.2) to 10 | 1 | ND(22) | ND(6.4) to ND(41) | 0 |
| OCDF | 2.2 | ND(2.8) to 4.3 | 8 | 22 | ND(54) to 168 | 8 | 190 | ND(180) to 230 | 8 |
| Total 2,3,7,8-CDD ^{a,b} | 55.7 | | | 798 | | | 3,212 | | |
| Total 2,3,7,8-CDF ^{a,b} | 18 | | | 272.5 | | | 310 | | |
| Total I-TEQ _{DF} (nondetect = 0) ^b | 8.28 | | | 90.12 | | | 58.89 | | |
| Total I-TEQ _{DF} (nondetect = 1/2 DL) ^b | 8.56 | | | 91.72 | | | 66.57 | | |
| Total TEQ _{DF} -WHO ₉₈ (nondetect = 0) ^b | 8.24 | | 89.47 | | | | 56.02 | | |
| Total TEQ _{DF} -WHO ₉₈ (nondetect = 1/2 DL) ^b | 8.59 | | 91.7 | | | | 66.09 | | |
| Total CDD/CDF ^b | 120 | | | 1,695 | | | 4,013 | | |

^aCalculated assuming nondetect values were zero.^bSum of median values.

DL = Detection limit

ND = Not detected (value in parenthesis is the detection limit)

Source: U.S. EPA (1990a).

Table 8-2. CDD/CDF concentrations in pulp and paper mill bleached pulp, wastewater sludge, and wastewater effluent (mid-1990s)

| Congener/congener group | Bleached pulp | | | | Wastewater sludge | | | | Wastewater effluent | | | |
|--|----------------------------|----------------|-----------------|------------------------|----------------------------|----------------|------------------|------------------------|---------------------------|----------------|--------------------|------------------------|
| | Mean nondetect = 0 (ng/kg) | Median (ng/kg) | Range (ng/kg) | No. of detects/samples | Mean nondetect = 0 (ng/kg) | Median (ng/kg) | Range (ng/kg) | No. of detects/samples | Mean nondetect = 0 (pg/L) | Median (ng/kg) | Range (pg/L) | No. of detects/samples |
| 2,3,7,8-TCDD | 0.3 | ND(1) | ND(1) to 5 | 1/18 | 0.8 | ND(1) | ND(1) to 4 | 4/12 | 1.2 | ND(11) | ND(10) to 21 | 1/18 |
| 1,2,3,7,8-PeCDD | 0 | ND(5) | ND(3) to ND(7) | 0/18 | 0 | ND(5) | ND(4) to ND(52) | 0/12 | 0 | ND(53) | ND(50) to ND(55) | 0/18 |
| 1,2,3,4,7,8-HxCDD | 0 | ND(5) | ND(3) to ND(7) | 0/18 | 0.5 | ND(5) | ND(4) to 7 | 1/13 | 0 | ND(53) | ND(50) to ND(55) | 0/18 |
| 1,2,3,6,7,8-HxCDD | 0 | ND(5) | ND(3) to ND(7) | 0/18 | 2.3 | ND(5) | ND(4) to 18 | 2/13 | 0 | ND(53) | ND(50) to ND(55) | 0/18 |
| 1,2,3,7,8,9-HxCDD | 0 | ND(5) | ND(3) to ND(7) | 0/18 | 1.6 | ND(5) | ND(4) to 14 | 2/13 | 0 | ND(53) | ND(50) to ND(55) | 0/18 |
| 1,2,3,4,6,7,8-HpCDD | 0 | ND(5) | ND(3) to ND(7) | 0/18 | 41.4 | 7 | ND(4) to 330 | 9/13 | 3.2 | ND(53) | ND(50) to 58 | 1/18 |
| OCDD | 2.4 | ND(10) | ND(10) to 15 | 3/16 | 445 | 150 | 21 to 2,900 | 10/10 | 99 | ND(110) | ND(100) to 370 | 6/14 |
| 2,3,7,8-TCDF | 10.3 | ND(1) | ND(1) to 170 | 7/18 | 6.2 | 3 | ND(1) to 31 | 9/12 | 2.3 | ND(11) | ND(10) to 23 | 2/18 |
| 1,2,3,7,8-PeCDF | 0 | ND(5) | ND(3) to ND(7) | 0/18 | 0 | ND(5) | ND(4) to ND(52) | 0/13 | | ND(53) | ND(50) to ND(55) | 0/18 |
| 2,3,4,7,8-PeCDF | 0.4 | ND(5) | ND(3) to 7 | 1/18 | 0.5 | ND(5) | ND(4) to 7 | 1/13 | | ND(53) | ND(50) to ND(55) | 0/18 |
| 1,2,3,4,7,8-HxCDF | 0 | ND(5) | ND(3) to ND(7) | 0/18 | 0 | ND(5) | ND(4) to ND(52) | 0/13 | | ND(53) | ND(50) to ND(55) | 0/18 |
| 1,2,3,6,7,8-HxCDF | 0 | ND(5) | ND(3) to ND(7) | 0/18 | 0 | ND(5) | ND(4) to ND(52) | 0/13 | | ND(53) | ND(50) to ND(55) | 0/18 |
| 1,2,3,7,8,9-HxCDF | 0 | ND(5) | ND(3) to ND(7) | 0/18 | 0 | ND(5) | ND(4) to ND(52) | 0/13 | | ND(53) | ND(50) to ND(55) | 0/18 |
| 2,3,4,6,7,8-HxCDF | 0 | ND(5) | ND(3) to ND(7) | 0/18 | 0.5 | ND(5) | ND(4) to 6 | 1/13 | | ND(53) | ND(50) to ND(55) | 0/18 |
| 1,2,3,4,6,7,8-HpCDF | 0 | ND(5) | ND(3) to ND(7) | 0/18 | 1.2 | ND(5) | ND(4) to 10 | 2/13 | | ND(53) | ND(50) to ND(55) | 0/18 |
| 1,2,3,4,7,8,9-HpCDF | 0 | ND(5) | ND(3) to ND(7) | 0/18 | 0 | ND(5) | ND(4) to ND(52) | 0/13 | | ND(53) | ND(50) to ND(55) | 0/18 |
| OCDF | 0 | ND(10) | ND(6) to ND(14) | 0/18 | 0 | ND(10) | ND(9) to ND(100) | 0/13 | | ND(106) | ND(104) to ND(110) | 0/18 |
| Total 2,3,7,8-CDD ^a | 2.7 | | | | 492 | | | | 103 | | | |
| Total 2,3,7,8-CDF ^a | 10.7 | | | | 8.4 | | | | 2.3 | | | |
| Total I-TEQ _{DF} (nondetect = 0) ^a | 1.53 | | | | 3 | | | | 1.5 | | | |
| Total I-TEQ _{DF} (nondetect = ½ DL) ^a | 6.4 | | | | 12.9 | | | | 53.6 | | | |
| Total TEQ _{DF} -WHO ₉₈ (nondetect = 0) ^a | 1.5 | | | | 2.6 | | | | 1.4 | | | |
| Total TEQ _{DF} -WHO ₉₈ (nondetect = ½ DL) ^a | 7.6 | | | | 15.2 | | | | 66.5 | | | |

^a Sum of mean values.

DL = Detection limit

ND = Not detected (value in parenthesis is the detection limit)

Source: Gillespie (1997).

Table 8-3. Summary of bleached chemical pulp and paper mill discharges of 2,3,7,8-TCDD and 2,3,7,8-TCDF (g/yr)

| Matrix | Congener | U.S. EPA 1988^a | NCASI 1992^b | U.S. EPA 1993^c | NCASI 1993^b | NCASI 1994^b | U.S. EPA 1995^d |
|---------------------|-----------------|--------------------------------------|-----------------------------------|--------------------------------------|-----------------------------------|-----------------------------------|--------------------------------------|
| Effluent | 2,3,7,8-TCDD | 201 | 22 | 71 | 19 | 14.6 | 16 |
| | 2,3,7,8-TCDF | 1,550 | 99 | 341 | 76 | 49 | 120 |
| | TEQ | 356 | 32 | 105 | 27 | 19.5 | 28 |
| Sludge ^e | 2,3,7,8-TCDD | 210 | 33 | -- | 24 | 18.9 | -- |
| | 2,3,7,8-TCDF | 1,320 | 118 | -- | 114 | 95.2 | -- |
| | TEQ | 343 | 45 | 177 | 35 | 28.4 | 50 |
| Pulp | 2,3,7,8-TCDD | 262 | 24 | -- | 22 | 16.2 | -- |
| | 2,3,7,8-TCDF | 2,430 | 124 | -- | 106 | 78.8 | -- |
| | TEQ | 505 | 36 | 149 | 33 | 24.1 | 40 |

^aThe total discharge rate of congener or TEQ (based only on 2,3,7,8-TCDD and 2,3,7,8-TCDF concentrations) was summed across all 104 mills. Data from 104 Mill Study (U.S. EPA, 1990a).

^bThe total discharge rate of congener or TEQ (based only on 2,3,7,8-TCDD and 2,3,7,8-TCDF concentrations) was summed across all 104 mills. The daily discharge rates reported in NCASI (1993) and Gillespie (1994, 1995) were multiplied by a factor of 350 days/yr to obtain estimates of annual discharge rates. 1992 NCASI survey (NCASI, 1993), 1993 update (Gillespie, 1994), and 1994 update (Gillespie, 1995).

^cThe discharges in effluent and sludge were estimated in U.S. EPA (1993d, 1997f) for January 1, 1993. The TEQ discharge in pulp was estimated by multiplying the 1988 discharge estimate by the ratio of the 1988 and 1993 effluent discharge estimates (i.e., the estimate of the reduction in 1988 discharges achieved by pollution prevention measures taken by the industry between 1988 and 1993).

^dThe discharges in effluent and sludge were estimated in U.S. EPA (1997f) for mid-1995. The TEQ discharge in pulp was estimated by multiplying the 1988 discharge estimate by the ratio of the 1988 and 1995 effluent discharge estimates (i.e., the estimate of the reduction in 1988 discharges achieved by pollution prevention measures taken by industry between 1988 and 1995).

^eApproximately 20.5% of the sludge generated in 1990 was incinerated. The remaining 79.5% was predominantly landfilled (56.5%) or placed in surface impoundments (18.1%); 4.1% was land-applied directly or as compost, and 0.3% was distributed or marketed (U.S. EPA, 1993e).

-- = No information given

Table 8-4. CDD/CDF TEQ concentrations and emissions for the paper and pulp industry by source

| Congener | Effluent | | Waste treatment residuals not lagooned or landfilled (sludge) (49% not landfilled) | | Pulp | |
|--------------------------|-------------------------------|-----------------------|--|-----------------------|------------------------------------|-----------------------|
| | TEQ conc. ^a (pg/L) | TEQ emissions (ng/yr) | TEQ conc. ^a (ng/kg) | TEQ emissions (ng/yr) | TEQ conc. ^a (pg/g pulp) | TEQ emissions (ng/yr) |
| 2,3,7,8-TCDD | 0 | 0.00e+00 | 4.00e-01 | 4.63e+08 | 1.00e-02 | 2.90e+08 |
| 1,2,3,7,8-PeCDD | 0.00e+00 | 0.00e+00 | 5.00e-02 | 6.24e+07 | 0.00e+00 | 0.00e+00 |
| 1,2,3,4,7,8-HxCDD | 0.00e+00 | 0.00e+00 | 1.00e-02 | 1.25e+07 | 0.00e+00 | 0.00e+00 |
| 1,2,3,6,7,8-HxCDD | 1.30e-01 | 2.71e+08 | 8.00e-02 | 8.53e+07 | 0.00e+00 | 0.00e+00 |
| 1,2,3,7,8,9-HxCDD | 9.00e-02 | 1.88e+08 | 9.00e-02 | 9.05e+07 | 0.00e+00 | 0.00e+00 |
| 1,2,3,4,6,7,8-HpCDD | 7.00e-02 | 1.46e+08 | 1.82e-01 | 1.97e+08 | 3.00e-03 | 8.69e+07 |
| 1,2,3,4,6,7,8,9-OCDD | 7.37e-02 | 1.54e+08 | 2.80e-01 | 2.81e+08 | 3.04e-03 | 8.80e+07 |
| 2,3,7,8-TCDF | 1.00e-01 | 2.08e+08 | 4.00e-01 | 4.66e+08 | 1.00e-03 | 2.90e+07 |
| 1,2,3,7,8-PeCDF | 0.00e+00 | 0.00e+00 | 1.00e-02 | 1.25e+07 | 0.00e+00 | 0.00e+00 |
| 2,3,4,7,8-PeCDF | 0.00e+00 | 0.00e+00 | 1.00e-01 | 1.25e+08 | 0.00e+00 | 0.00e+00 |
| 1,2,3,4,7,8-HxCDF | 0.00e+00 | 0.00e+00 | 4.00e-02 | 4.63e+07 | 0.00e+00 | 0.00e+00 |
| 1,2,3,6,7,8-HxCDF | 0.00e+00 | 0.00e+00 | 1.00e-02 | 1.25e+07 | 0.00e+00 | 0.00e+00 |
| 1,2,3,7,8,9-HxCDF | 0.00e+00 | 0.00e+00 | 5.00e-02 | 5.15e+07 | 2.00e-03 | 5.79e+07 |
| 2,3,4,6,7,8-HxCDF | 0.00e+00 | 0.00e+00 | 0.00e+00 | 0.00e+00 | 0.00e+00 | 0.00e+00 |
| 1,2,3,4,6,7,8-HpCDF | 1.90e-02 | 3.96e+07 | 1.70e-02 | 1.83e+07 | 1.00e-03 | 2.90e+07 |
| 1,2,3,4,7,8,9-HpCDF | 5.00e-03 | 1.04e+07 | 0.00e+00 | 0.00e+00 | 0.00e+00 | 0.00e+00 |
| 1,2,3,4,6,7,8,9-OCDF | 2.00e-03 | 4.17e+06 | 3.70e-03 | 3.93e+06 | 6.00e-05 | 1.74e+06 |
| TOTAL | 4.90e-01 | 1.02e+09 | 1.72 | | 2.01e-02 | 5.82e+08 |
| Residuals total | | | | 1.93e+09 | | |
| Residuals not landfilled | | | | 9.44e+08 | | |

^aTEQ concentrations are in TEQ_{DF}-WHO₉₈.

Source: Gillespie (2002).

Table 8-5. CDD/CDF concentrations in graphite electrode sludge from chlorine production (µg/kg)

| Congener/congener group | Sludge 1 | Sludge 2 | Sludge 3 | Sludge 4 |
|---|------------|------------|------------|------------|
| 2,3,7,8-TCDD | ND (0.006) | ND (0.009) | ND (0.009) | ND |
| 1,2,3,7,8-PeCDD | ND (0.007) | ND (0.009) | ND (0.009) | ND (0.033) |
| 1,2,3,4,7,8-HxCDD | ND (0.018) | ND (0.026) | ND (0.029) | ND (0.49) |
| 1,2,3,6,7,8-HxCDD | ND (0.012) | ND (0.016) | ND (0.019) | ND (0.053) |
| 1,2,3,7,8,9-HxCDD | ND (0.016) | ND (0.022) | ND (0.025) | ND (1.2) |
| 1,2,3,4,6,7,8-HpCDD | 0.095 | 0.21 | 0.25 | 0.055 |
| OCDD | 0.92 | 2 | 2.2 | 0.65 |
| 2,3,7,8-TCDF | 26 | 56 | 57 | 52 |
| 1,2,3,7,8-PeCDF | 25 | 55 | 56 | 55 |
| 2,3,4,7,8-PeCDF | 12 | 25 | 24 | 27 |
| 1,2,3,4,7,8-HxCDF | 32 | 71 | 73 | 44 |
| 1,2,3,6,7,8-HxCDF | 7 | 16 | 15 | 12 |
| 1,2,3,7,8,9-HxCDF | 1.3 | 2.8 | 2.6 | 1.7 |
| 2,3,4,6,7,8-HxCDF | 0.87 | 1.9 | 2 | 1.3 |
| 1,2,3,4,6,7,8-HpCDF | 9.1 | 19 | 19 | 15 |
| 1,2,3,4,7,8,9-HpCDF | 8.1 | 19 | 20 | 14 |
| OCDF | 31 | 76 | 71 | 81 |
| Total 2,3,7,8-CDD ^a | 1.02 | 2.21 | 2.45 | 0.7 |
| Total 2,3,7,8-CDF ^a | 152.37 | 341.7 | 339.6 | 303 |
| Total I-TEQ _{DF} ^a | 14.2 | 30.5 | 30.2 | 27.7 |
| Total TEQ _{DF} -WHO ₉₈ ^a | 14.1 | 30.4 | 30.2 | 27.6 |
| Total TCDD | ND (0.006) | ND (0.009) | ND (0.009) | -- |
| Total PeCDD | ND (0.070) | ND (0.009) | ND (0.009) | -- |
| Total HxCDD | ND (0.046) | ND (0.064) | ND (0.074) | -- |
| Total HpCDD | 0.22 | 0.48 | 0.56 | -- |
| Total OCDD | 0.92 | 2 | 2.2 | 0.65 |
| Total TCDF | 64 | 150 | 140 | -- |
| Total PeCDF | 75 | 240 | 240 | -- |
| Total HxCDF | 68 | 140 | 140 | -- |
| Total HpCDF | 24 | 53 | 54 | -- |
| Total OCDF | 31 | 76 | 71 | 81 |
| Total CDD/CDF ^a | 263.14 | 661.48 | 647.76 | -- |

^aCalculated assuming nondetect values were zero.

ND = Not detected (value in parenthesis is the reported detection limit)

-- = No information given

Sources: Rappe et al. (1991); Rappe (1993).

Table 8-6. CDD/CDF concentrations in metal chlorides (µg/kg)

| Congener group | FeCl₃ | AlCl₃^a | AlCl₃^a | CuCl₂ | CuCl | TiCl₄ | SiCl₄ |
|-----------------------|-------------------------|-------------------------------------|-------------------------------------|-------------------------|-------------|-------------------------|-------------------------|
| Total TCDD | -- | -- | -- | -- | -- | -- | -- |
| Total PeCDD | -- | -- | -- | -- | -- | -- | -- |
| Total HxCDD | -- | -- | -- | -- | -- | -- | -- |
| Total HpCDD | ND | ND | ND | 0.03 | ND | ND | ND |
| Total OCDD | ND | ND | 0.1 | 0.6 | 0.03 | ND | ND |
| Total TCDF | -- | -- | -- | -- | -- | -- | -- |
| Total PeCDF | -- | -- | -- | -- | -- | -- | -- |
| Total HxCDF | -- | -- | -- | -- | -- | -- | -- |
| Total HpCDF | 12 | ND | ND | 0.1 | 0.08 | ND | ND |
| Total OCDF | 42 | ND | 34 | 0.5 | 0.2 | ND | ND |

^aAlCl₃ was tested twice.

ND = Not detected; detection limit of 0.02 µg/kg

-- = No information given

Source: Hutzinger and Fiedler (1991a).

Table 8-7. CDD/CDF concentrations in mono- through tetrachlorophenols (mg/kg)

| Congener/ congener group | 2-CP^a | 2,4-DCP^a | 2,6-DCP^a | 2,4,5-TrCP (Na salt)^a | 2,4,5-TrCP^a | 2,4,6-TrCP^a | 2,4,6-TrCP (Na salt)^{b, c} | 2,3,4,6-TeCP^a | 2,3,4,6-TeCP (Na salt)^{b, c} |
|-------------------------------------|-------------------------|----------------------------|----------------------------|---|-------------------------------|-------------------------------|--|---------------------------------|--|
| Total TCDD | ND (0.02) | ND (0.02) | ND (0.02) | ND (0.02) to 14 | ND (0.02) to 6.5 | ND (0.02) to 49 | <0.02 | ND (0.02) | 0.7 |
| Total PeCDD | ND (0.02) | ND (0.02) | ND (0.02) | ND (0.02) | ND (0.02) to 1.5 | ND (0.02) | <0.03 | ND (0.02) | 5.2 |
| Total HxCDD | ND (0.02) | ND (0.02) | ND (0.02) | ND (0.02) | ND (0.02) | ND (0.02) | <0.03 | ND (0.02) to 15 | 9.5 |
| Total HpCDD | ND (0.02) | ND (0.02) | ND (0.02) | ND (0.02) | ND (0.02) | ND (0.02) | <0.1 | ND (0.02) to 5.1 | 5.6 |
| Total OCDD | ND (0.02) | ND (0.02) | ND (0.02) | ND (0.02) | ND (0.02) | ND (0.02) | <0.1 | ND (0.02) to 0.17 | 0.7 |
| Total TCDF | + | ND | ND | ND | ND | + | 1.5 | + | 0.5 |
| Total PeCDF | ND | ND | ND | ND | ND | + | 17.5 | + | 10 |
| Total HxCDF | ND | ND | ND | ND | ND | + | 36 | + | 70 |
| Total HpCDF | ND | ND | ND | ND | ND | ND | 4.8 | + | 70 |
| Total OCDF | ND | ND | ND | ND | ND | ND | -- | + | 10 |
| TOTAL | -- | -- | -- | -- | -- | -- | -- | -- | -- |

^aSource: Firestone et al. (1972); because of poor recoveries, authors stated that actual CDD/CDF levels may have been considerably higher than those reported.

^bSource: Rappe et al. (1978a); common Scandinavian commercial chlorophenols.

^cSource: Rappe et al. (1978b); common Scandinavian commercial chlorophenols.

ND = Not detected (value in parenthesis is the detection limit, if reported)

+ = Detected but not quantified

-- = No information given

Table 8-8. CDD/CDF concentrations (historical and current) in technical-grade pentachlorophenol (PCP) products (µg/kg)

| Congener/ congener group | 1973 ^a | 1978 ^b | 1979 ^c | 1984 ^d | 1985 | 1986 | 1987 ^e | 1987 ^g | 1985–88 ^e | 1991 ^h | 1988–99 ⁱ | 1988–99 ⁱ | Un- known ^k |
|---|-------------------|-------------------|-------------------|-------------------|-----------|-----------|-------------------|-------------------|----------------------|-------------------|----------------------|----------------------|---------------------------|
| 2,3,7,8-TCDD | -- | -- | -- | ND (10) | ND (0.05) | ND (0.05) | ND (0.03) | ND (0.05) | ND (0.05) | ND | -- | ND (0.5) | ND (10) |
| 1,2,3,7,8-PeCDD | -- | -- | -- | ND (10) | ND (1) | ND (1) | 1 | 2 | ND (1) | ND | -- | -- | ND (10) |
| 1,2,3,4,7,8-HxCDD | -- | -- | -- | -- | 6 | 8 | ND (1) | ND (1) | 8 | -- | -- | -- | ND (10) |
| 1,2,3,6,7,8-HxCDD | -- | -- | -- | 2,200 | 2,565 | 1,532 | 831 | 1,480 | 600 | -- | -- | -- | 860 |
| 1,2,3,7,8,9-HxCDD | -- | -- | -- | 100 | 44 | 28 | 28 | 53 | 13 | -- | -- | -- | 20 |
| 1,2,3,4,6,7,8-HpCDD | -- | -- | -- | 100,000 | 210,000 | 106,000 | 78,000 | 99,900 | 89,000 | -- | -- | -- | 36,400 |
| OCDD | -- | -- | -- | 610,000 | 1,475,000 | 930,000 | 733,000 | 790,000 | 2,723,000 | 1,100,000 | -- | -- | 296,810 |
| 2,3,7,8-TCDF | -- | -- | -- | ND (10) | ND (0.5) | ND (0.5) | ND (0.1) | ND (0.1) | ND (0.5) | ND | -- | -- | ND (10) |
| 1,2,3,7,8-PeCDF | -- | -- | -- | -- | ND (1) | ND (1) | 0.5 | 0.2 | ND (1) | ND | -- | -- | ND (10) |
| 2,3,4,7,8-PeCDF | -- | -- | -- | -- | ND (1) | ND (1) | 1.5 | 0.9 | ND (1) | ND | -- | -- | ND (10) |
| 1,2,3,4,7,8-HxCDF | -- | -- | -- | -- | 49 | 34 | 125 | 163 | 67 | -- | -- | -- | 200 |
| 1,2,3,6,7,8-HxCDF | -- | -- | -- | -- | 5 | 4 | ND (1) | ND (1) | 2 | -- | -- | -- | ND (20) |
| 1,2,3,7,8,9-HxCDF | -- | -- | -- | -- | 5 | ND (1) | 32 | 146 | ND (1) | -- | -- | -- | ND (20) |
| 2,3,4,6,7,8-HxCDF | -- | -- | -- | -- | ND (1) | ND (1) | ND (1) | ND (1) | ND (1) | -- | -- | -- | ND (20) |
| 1,2,3,4,6,7,8-HpCDF | -- | -- | -- | -- | 34,000 | 29,000 | 11,280 | 19,940 | 22,000 | -- | -- | -- | 2,000 |
| 1,2,3,4,7,8,9-HpCDF | -- | -- | -- | -- | 4,100 | 6,200 | 637 | 980 | 3,400 | -- | -- | -- | 140 |
| OCDF | -- | 130,000 | -- | 130,000 | 222,000 | 233,000 | 118,000 | 137,000 | 237,000 | 170,000 | -- | -- | 19,940 |
| Total 2,3,7,8-CDD ^l | -- | -- | -- | 712,300 | 1.688e+20 | 1.038e+20 | 811,860 | 891,435 | 2.813e+20 | -- | -- | -- | 334,090 |
| Total 2,3,7,8-CDF ^l | -- | -- | -- | -- | -- | -- | 130,076 | 158,230 | -- | -- | -- | -- | 22,280 |
| Total I-TEQ _{DF} ^l | -- | -- | -- | 1,970 | -- | -- | 1,853 | 2,321 | -- | ≥1,270 | -- | -- | 810 |
| Total TEQ _{DF} -WHO ₉₈ ^l | -- | -- | -- | 1,304 | -- | -- | 1,088 | 1,488 | -- | >127 | -- | -- | 525 |
| Total TCDD | ND(20) | -- | -- | ND (10) | ND | ND | 1.9 | 0.4 | ND | ND (10) | ND (1) | ND | -- |
| Total PeCDD | ND(30) | -- | -- | ND (10) | ND | ND | 6.5 | 15.2 | ND | ND (10) | ND (10) | 3 | -- |
| Total HxCDD | 5,500 | -- | 10,100 | 4,500 | 4,694 | 2,925 | 1,700 | 3,300 | 912 | 8,900 | 1,440 | 1,490 | -- |
| Total HpCDD | 98,000 | -- | 296,000 | 135,000 | 283,000 | 134,000 | 154,000 | 198,000 | 117,000 | 130,000 | 55,560 | 48,430 | -- |
| Total OCDD | 220,000 | -- | 1,386,000 | 610,000 | 1,475,000 | 930,000 | 733,000 | 790,000 | 2,723,000 | 1,100,000 | -- | 191,700 | -- |
| Total TCDF | 40 | 900 | -- | ND (10) | 6 | ND | 0.8 | 0.4 | ND | ND (10) | ND (10) | 48 | -- |
| Total PeCDF | 250 | 4,000 | 1,400 | -- | 10 | 3 | 141 | 343 | 200 | ND (10) | ND (10) | 520 | -- |
| Total HxCDF | 22,000 | 32,000 | 9,900 | -- | 1,982 | 1,407 | 4,300 | 13,900 | 1,486 | 14,000 | 3,070 | 13,650 | -- |
| Total HpCDF | 150,000 | 120,000 | 88,000 | 62,000 | 125,000 | 146,000 | 74,000 | 127,000 | 99,000 | 36,000 | 36,530 | 76,090 | -- |
| Total OCDF | 160,000 | 130,000 | 43,000 | 130,000 | 222,000 | 233,000 | 118,000 | 137,000 | 237,000 | 170,000 | -- | 136,310 | -- |
| Total CDD/CDF ^l | 655,800 | 1,280,000 | 1,834,400 | 941,500 | 2,111,692 | 1,447,335 | 1,085,000 | 1,270,000 | 3,178,598 | 1,459,000 | -- | 468,240 | -- |

^aSource: Buser and Bosshardt (1976); mean of 10 samples of “high” CDD/CDF-content PCP received from Swiss commercial sources in 1973.

^bSource: Rappe et al. (1978b); sample of U.S. origin, “presumably prepared by alkaline hydrolysis of hexachlorobenzene.”

^cSource: U.S. Department of Health and Human Services (1989); composite of technical-grade materials produced in 1979 by Monsanto Industrial Chemical Co. (St. Louis, MO), Reichhold Chemicals, Inc. (White Plains, NY), and Vulcan Materials Co. (Birmingham, AL).

^dSource: Cull et al. (1984); mean of four “recent” production batches from each of two manufacturers of technical PCP using three different analytical methods; ANOVA showed no statistically significant difference in CDD/CDF concentrations between the eight samples (samples obtained in the United Kingdom).

^eSource: Pentachlorophenol Task Force (1997); samples of “penta” manufactured in 1985, 1986, and 1988.

^fSource: Hagenmaier and Brunner (1987); sample of Witophen P (Dynamit Nobel - Lot no. 7777) (obtained in Germany).

^gSource: Hagenmaier and Brunner (1987); sample of PCP produced by Rhone Poulenc (obtained in Germany).

^hSource: Harrad et al. (1991); PCP-based herbicide formulation from NY State Dept. Environmental Conservation.

ⁱSource: Pentachlorophenol Task Force (1997); average of monthly batch samples for the period January 1987 to August 1996.

Table 8-8. CDD/CDF concentrations (historical and current) in technical pentachlorophenol (PCP) products (µg/kg) (continued)

^jSource: KMG-Bermuth, Inc. (1997); average of monthly batch samples for the period February 1987 to December 1996 (excluding the following months, for which data were not available: February 1993, January 1992, December 1991, September 1991, December 1988, and September 1988).

^kSource: Schecter et al. (1997); sample found stored in a barn in Vermont.

^lCalculated assuming nondetects were zero.

^kSource: Schecter et al. (1997); sample found stored in a barn in Vermont.

^lCalculated assuming nondetects were zero.

ND = Not detected (value in parenthesis is the detection limit)

-- = No information given

Table 8-9. Historical CDD/CDF concentrations in pentachlorophenol-Na (PCP-Na) (µg/kg)

| Congener/congener group | 1969 ^a | 1973 ^b | 1973 ^c | 1987 ^d | 1987 | 1992 ^f | 1980s ^g |
|---|-------------------|-------------------|-------------------|-------------------|--------|-------------------|--------------------|
| 2,3,7,8-TCDD | -- | -- | -- | 0.23 | 0.51 | 0.076 | ND (1.4) |
| 1,2,3,7,8-PeCDD | -- | -- | -- | 18.2 | 3.2 | 18.7 | 28.3 |
| 1,2,3,4,7,8-HxCDD | -- | -- | -- | 28.3 | 13.3 | 96 | ND (6.1) |
| 1,2,3,6,7,8-HxCDD | -- | -- | -- | 2,034 | 53 | 4,410 | 4,050 |
| 1,2,3,7,8,9-HxCDD | -- | -- | -- | 282 | 19 | 328 | ND (1.4) |
| 1,2,3,4,6,7,8-HpCDD | -- | -- | -- | 9,100 | 3,800 | 175,400 | 33,800 |
| OCDD | 3,600 | -- | -- | 41,600 | 32,400 | 879,000 | 81,000 |
| 2,3,7,8-TCDF | -- | -- | -- | 1.8 | 0.79 | ND (1) | 149 |
| 1,2,3,7,8-PeCDF | -- | -- | -- | 8.2 | 1.9 | ND (4) | 319 |
| 2,3,4,7,8-PeCDF | -- | -- | -- | 6.6 | 1.1 | ND (4) | 324 |
| 1,2,3,4,7,8-HxCDF | -- | -- | -- | 48 | 4.6 | 27.6 | ND (2.8) |
| 1,2,3,6,7,8-HxCDF | -- | -- | -- | 69 | 1.3 | 21.9 | 225 |
| 1,2,3,7,8,9-HxCDF | -- | -- | -- | ND (1) | 1.3 | 9.8 | 480 |
| 2,3,4,6,7,8-HxCDF | -- | -- | -- | 87 | 4.6 | 103 | ND (385) |
| 1,2,3,4,6,7,8-HpCDF | -- | -- | -- | 699 | 197 | 9,650 | 6,190 |
| 1,2,3,4,7,8,9-HpCDF | -- | -- | -- | 675 | 36 | 2,080 | 154 |
| OCDF | -- | -- | -- | 37,200 | 4,250 | 114,600 | 36,000 |
| Total 2,3,7,8-CDD ^h | -- | -- | -- | 53,063 | 35,289 | 1,059,253 | 118,878 |
| Total 2,3,7,8-CDF ^h | -- | -- | -- | 38,795 | 4,499 | 126,492 | 43,841 |
| Total I-TEQ _{DF} ^h | -- | -- | -- | 452 | 79.5 | 3,374 | 1,201 |
| Total TEQ _{DF} -WHO ₉₈ ^h | -- | -- | -- | 406 | 58.5 | 2,566 | 1,096 |
| Total TCDD | -- | 140 | 50 | 27 | 52 | 3.6 | 1.9 |
| Total PeCDD | -- | 40 | ND (30) | 213 | 31 | 142.7 | 140 |
| Total HxCDD | 17,000 | 140 | 3,400 | 3,900 | 230 | 9,694 | 14,000 |
| Total HpCDD | 9,600 | 1,600 | 38,000 | 18,500 | 5,800 | 260,200 | 100,000 |
| Total OCDD | 3,600 | 4,000 | 110,000 | 41,600 | 32,400 | 879,000 | 81,000 |
| Total TCDF | -- | ND (20) | ND (20) | 82 | 12 | 10.1 | 1,200 |
| Total PeCDF | -- | 60 | 40 | 137 | 27 | 88.4 | 6,400 |
| Total HxCDF | -- | 1,400 | 11,000 | 3,000 | 90 | 9,082.3 | 49,000 |
| Total HpCDF | -- | 4,300 | 47,000 | 13,200 | 860 | 75,930 | 91,000 |
| Total OCDF | -- | 4,300 | 26,500 | 37,200 | 4,250 | 114,600 | 36,000 |
| Total CDD/CDF ^h | -- | 15,980 | 235,990 | 117,859 | 43,752 | 1,348,751 | 378,742 |

^aSource: Firestone et al. (1972); mean of two samples of PCP-Na obtained in the United States between 1967 and 1969.

^bSource: Buser and Bosshardt (1976); mean of five samples of "low" CDD/CDF-content PCP-Na received from Swiss commercial sources.

^cSource: Buser and Bosshardt (1976); sample of "high" CDD/CDF-content PCP-Na received from a Swiss commercial source.

^dSource: Hagenmaier and Brunner (1987); sample of Dowicide-G purchased from Fluka; sample obtained in Germany.

^eSource: Hagenmaier and Brunner (1987); sample of Preventol PN (Bayer AG); sample obtained in Germany.

^fSource: Santl et al. (1994); 1992 sample of PCP-Na from Prolabo, France.

^gSource: Palmer et al. (1988); sample of a PCP-Na formulation collected from a closed sawmill in California in the late 1980s.

^hCalculated assuming nondetect values were zero.

ND = Not detected (value in parenthesis is the detection limit).

-- = No information given.

Table 8-10. Summary of specific dioxin-containing wastes that must comply with land disposal restrictions^a

| EPA hazardous waste number | Waste description | Land disposal restriction effective date | Regulated waste constituent |
|-----------------------------------|--|---|--|
| F020 | Wastes (except wastewater and spent carbon from HCl purification) from the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tri- or tetrachlorophenol or of intermediates used to produce their pesticide derivatives. (This listing does not include wastes from the production of hexachlorophene from highly purified 2,4,5-trichlorophenol.) | November 8, 1988 | TCDDs PeCDDs HxCDDs TCDFs PeCDFs HxCDFs |
| F021 | Wastes (except wastewater and spent carbon from HCl purification) from the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of pentachlorophenol or of intermediates used to produce its derivatives. | November 8, 1988 | TCDDs PeCDDs HxCDDs TCDFs PeCDFs HxCDFs |
| F022 | Wastes (except wastewater and spent carbon from HCl purification) from the manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tetra-, penta-, or hexachlorobenzenes under alkaline conditions. | November 8, 1988 | TCDDs PeCDDs HxCDDs TCDFs PeCDFs HxCDFs |
| F023 | Wastes (except wastewater and spent carbon from HCl purification) from the production of materials on equipment previously used for the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tri- and tetrachlorophenols. (This listing does not include wastes from equipment used only for the production or use of hexachlorophene from highly purified 2,4,5-trichlorophenol.) | November 8, 1988 | TCDDs PeCDDs HxCDDs TCDFs PeCDFs HxCDFs |
| F026 | Wastes (except wastewater and spent carbon from HCl purification) from the production of materials on equipment previously used for the manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tetra-, penta-, or hexachlorobenzene under alkaline conditions. | November 8, 1988 | TCDDs PeCDDs HxCDDs TCDFs PeCDFs HxCDFs |

Table 8-10. Summary of specific dioxin-containing wastes that must comply with land disposal restrictions^a (continued)

| EPA hazardous waste number | Waste description | Land disposal restriction effective date | Regulated waste constituent |
|-----------------------------------|---|--|--|
| F027 | Discarded unused formulations containing tri-, tetra-, or pentachlorophenol or discarded unused formulations containing compounds derived from these chlorophenols. (This listing does not include formulations containing hexachlorophene synthesized from prepurified 2,4,5-trichlorophenol as the sole component.) | November 8, 1988 | TCDDs PeCDDs HxCDDs TCDFs PeCDFs HxCDFs |
| F028 | Residues resulting from the incineration or thermal treatment of soil contaminated with EPA Hazardous Wastes No. F020–F023, F026, and F027 | November 8, 1988 | TCDDs PeCDDs HxCDDs TCDFs PeCDFs HxCDFs |
| F039 | Leachate (liquids that have percolated through land-disposed wastes) resulting from the disposal of more than one restricted waste classified as hazardous under subpart D of 40 CFR 268. (Leachate resulting from the disposal of one or more of the following EPA Hazardous Wastes and no other Hazardous Wastes retains its EPA Hazardous Waste Number(s): F020, F021, F022, F026, F027, and/or F028.) | August 8, 1990 (wastewater) May 8, 1992 (nonwastewater) | TCDDs PeCDDs HxCDDs TCDFs PeCDFs HxCDFs |
| K043 | 2,6-Dichlorophenol waste from the production of 2,4-D | June 8, 1989 | TCDDs PeCDDs HxCDDs TCDFs PeCDFs HxCDFs |
| K099 | Untreated wastewater from the production of 2,4-D | August 8, 1988 | TCDDs PeCDDs HxCDDs TCDFs PeCDFs HxCDFs |

^aFor wastewater, the treatment standard for all regulated waste constituents except PeCDFs is 0.063 µg/L; the standard for PeCDFs is 0.035 µg/L. For nonwastewater, the treatment standard for all regulated waste constituents is 1 µg/kg. Treatment standards are based on incineration to 99.9999% destruction and removal efficiency.

Source: 40 CFR 268.

Table 8-11. CDD/CDF concentrations in chlorobenzenes (µg/kg)

| Congener/congener group | MCBz^a | 1,2-DCBz (for synthesis)^a | 1,2,4-TrCBz (“pure”)^b | Mixed TrCBz (47%)^a | 1,2,4,5-TeC Bz (99%)^a | PeCBz (98%)^a | HCBz (97%)^a | HCBz^b |
|--------------------------------|-------------------------|---|---|--------------------------------------|---|--------------------------------|-------------------------------|-------------------------|
| Total TCDD | ND (0.02) | 0.3 | ND (0.1) | 0.027 | ND (0.02) | ND (0.02) | ND (20) | -- |
| Total PeCDD | ND (0.02) | ND (0.02) | ND (0.1) | 0.14 | 0.2 | ND (0.02) | ND (20) | -- |
| Total HxCDD | ND (0.02) | ND (0.02) | ND (0.1) | 0.259 | 0.5 | 0.02 | ND (20) | -- |
| Total HpCDD | ND (0.02) | ND (0.02) | ND (0.1) | 0.253 | 0.8 | 0.02 | 470 | -- |
| Total OCDD | ND (0.02) | ND (0.02) | ND (0.1) | 0.081 | 0.4 | 0.05 | 6,700 | 50–212,000 |
| Total TCDF | ND (0.02) | ND (0.02) | ND (0.1) | 0.736 | 0.03 | 0.02 | ND (20) | -- |
| Total PeCDF | ND (0.02) | 0.5 | ND (0.1) | 0.272 | 0.2 | ND (0.02) | ND (20) | -- |
| Total HxCDF | ND (0.02) | ND (0.02) | ND (0.1) | 0.091 | 0.8 | ND (0.02) | ND (20) | -- |
| Total HpCDF | ND (0.02) | ND (0.02) | ND (0.1) | 0.03 | 1.5 | 0.1 | 455 | -- |
| Total OCDF | ND (0.02) | ND (0.02) | ND (0.1) | 0.016 | 2.1 | 0.1 | 2,830 | 350–58,300 |
| Total CDD/CDF | -- | -- | -- | 1.904 | -- | -- | -- | -- |

^aSource: Hutzinger and Fiedler (1991a); unpublished results of tests performed at the University of Bayreuth, Germany, and by Dr. H. Hagenmaier.

^bSource: Villanueva et al. (1974); range of three samples of commercially available HCBz.

ND = Not detected (value in parenthesis is the detection limit, if reported)

-- = No information given

Table 8-12. Concentrations of CDD/CDF congener groups in unused commercial polychlorinated biphenyl (PCB) mixtures (mg/kg)

| PCB mixture | Year of manufacture | CDF congener group concentrations | | | | | | CDD congener group concentrations | | | | | | Source |
|----------------|---------------------|-----------------------------------|--------|-------|-------|-------|-----------|-----------------------------------|-------|-------|-------|-------|-----------|--------|
| | | TCDF | PeCDF | HxCDF | HpCDF | OCDF | Total CDF | TCDD | PeCDD | HxCDD | HpCDD | OCDD | Total CDD | |
| Aroclor 1016 | 1972 | ND | ND | ND | -- | -- | ND | -- | -- | -- | -- | -- | -- | a |
| Aroclor 1242 | -- | 0.07 | 0.03 | 0.003 | -- | -- | 0.15 | -- | -- | -- | -- | -- | -- | b, c |
| Aroclor 1242 | -- | 2.3 | 2.2 | ND | -- | -- | 4.5 | -- | -- | -- | -- | -- | -- | b, c |
| Aroclor 1242 | -- | 0.25 | 0.7 | 0.81 | -- | -- | 1.9 | -- | -- | -- | -- | -- | -- | b |
| Clophen A-30 | -- | 6.377 | 2.402 | 0.805 | 0.108 | 0.016 | 9.708 | 0.0007 | ND | 0.001 | 0.006 | 0.031 | 0.039 | e |
| Clophen A-30 | -- | 0.713 | 0.137 | 0.005 | 0.001 | ND | 0.855 | ND | ND | ND | 0.005 | 0.025 | 0.03 | d |
| Aroclor 1248 | 1969 | 0.5 | 1.2 | 0.3 | -- | -- | 22.2352 | -- | -- | -- | -- | -- | -- | b |
| Clophen A-40 | -- | 1.289 | 0.771 | 0.144 | 0.02 | 0.011 | | ND | ND | ND | 0.012 | 0.03 | 0.042 | d |
| Kanechlor 400 | -- | -- | -- | -- | -- | -- | | -- | -- | -- | -- | -- | -- | b, c |
| Aroclor 1254 | 1969 | 0.1 | 0.2 | 1.4 | -- | -- | 1.7 | -- | -- | -- | -- | -- | -- | a |
| Aroclor 1254 | 1970 | 0.2 | 0.4 | 0.9 | -- | -- | 1.5 | -- | -- | -- | -- | -- | -- | a |
| Aroclor 1254 | -- | 0.02 | 0.2 | 0.6 | -- | -- | 0.8 | -- | -- | -- | -- | -- | -- | b, c |
| Aroclor 1254 | -- | 0.05 | 0.1 | 0.02 | -- | -- | 0.2 | -- | -- | -- | -- | -- | -- | b |
| Clophen A-50 | -- | 5.402 | 2.154 | 2.214 | 0.479 | 0.069 | 10.318 | ND | ND | ND | 0.011 | 0.027 | 0.038 | d |
| Aroclor 1260 | -- | 0.3 | 1 | 1.1 | 1.35 | -- | 3.8 | -- | -- | -- | -- | -- | -- | b, c |
| Aroclor 1260 | 1969 | 0.1 | 0.4 | 0.5 | -- | -- | 1 | -- | -- | -- | -- | -- | -- | a |
| Aroclor 1260 | -- | 0.8 | 0.9 | 0.5 | -- | -- | 2.2 | -- | -- | -- | -- | -- | -- | b, c |
| Aroclor 1260 | -- | 0.2 | 0.3 | 0.3 | -- | -- | 0.8 | -- | -- | -- | -- | -- | -- | a |
| Clophen A-60 | -- | 15.786 | 11.655 | 4.456 | 1.517 | 0.639 | 34.052 | 0.0004 | 0.002 | 0.002 | 0.003 | 0.015 | 0.022 | e |
| Clophen A-60 | -- | 16.34 | 21.164 | 7.63 | 2.522 | 1.024 | 48.681 | ND | ND | ND | 0.014 | 0.032 | 0.046 | d |
| Clophen A-60 | -- | 1.4 | 5 | 2.2 | -- | -- | 8.6 | -- | -- | -- | -- | -- | -- | a |
| Phenoclor DP-6 | -- | 0.7 | 10 | 2.9 | -- | -- | 13.6 | -- | -- | -- | -- | -- | -- | a |
| Clophen T-64 | -- | 0.3 | 1.73 | 2.45 | 0.82 | -- | 5.4 | -- | -- | -- | -- | -- | -- | b |
| Prodelec 3010 | -- | 1.08 | 0.35 | 0.07 | -- | -- | 2 | -- | -- | -- | -- | -- | -- | b |

^aSource: Bowes et al. (1975a).^bSource: Erickson (1986).^cSource: ATSDR (1993).^dSource: Hagenmaier (1987).^eSource: Malisch (1994).

ND = Not detected

-- = No information given

Table 8-13. 2,3,7,8-Substituted congener concentrations in unused polychlorinated biphenyl (PCB) mixtures (µg/kg)

| Congener | Congener concentrations in Clophens | | | | | | Congener concentrations in Aroclors | | | | | | | | | |
|---|-------------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| | A-30 ^a | A-30 ^b | A-40 ^b | A-50 ^b | A-60 ^a | A-60 ^b | 1016 ^c | 1242 ^c | 1248 ^d | 1254 ^c | 1254 ^c | 1254 ^c | 1254 ^d | 1260 ^c | 1260 ^c | 1260 ^c |
| 2,3,7,8-TCDD | ND | ND | ND | ND | ND | ND | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1,2,3,7,8-PeCDD | ND | ND | ND | ND | 0.1 | ND | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1,2,3,4,7,8-HxCDD | ND | ND | ND | ND | 0.2 | ND | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1,2,3,6,7,8-HxCDD | 0.8 | ND | ND | ND | ND | ND | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1,2,3,7,8,9-HxCDD | ND | ND | ND | ND | ND | ND | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1,2,3,4,6,7,8-HpCDD | 5.6 | 2.4 | 4.4 | 5.3 | 2.5 | 6.8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| OCDD | 31.1 | 24.7 | 30.3 | 26.9 | 14.9 | 32.3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2,3,7,8-TCDF | 1,032.6 | 36.9 | 250.2 | 1,005.7 | 2,287.7 | 3,077.2 | 0.1 | 40.1 | 330 | 28 | 20.9 | 55.8 | 110 | 63.5 | 6.88 | 29 |
| 1,2,3,7,8-PeCDF | 135.8 | 14.9 | 52.7 | 155.2 | 465.2 | 1,750.8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2,3,4,7,8-PeCDF | 509.2 | 13.1 | 171.3 | 407.5 | 1,921.9 | 2,917.0 | 1.75 | 40.8 | 830 | 110 | 179 | 105 | 120 | 135 | 58.2 | 112 |
| 1,2,3,4,7,8-HxCDF | 301.4 | 1.9 | 48.4 | 647.5 | 1,604.2 | 2,324.1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1,2,3,6,7,8-HxCDF | 65.3 | 0.8 | 19.6 | 227.5 | 157.6 | 351.3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1,2,3,7,8,9-HxCDF | ND | ND | 0.7 | 8.3 | 42.8 | 19 | 0.08 | 0.26 | -- | 28.8 | 28.7 | 19.4 | -- | 5.1 | 9.7 | 10.7 |
| 2,3,4,6,7,8-HxCDF | 50.6 | 0.1 | 6.8 | 62.5 | 369.5 | 4,08.3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1,2,3,4,6,7,8-HpCDF | 43.7 | 0.6 | 7 | 205.5 | 480.6 | 1,126.1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1,2,3,4,7,8,9-HpCDF | 22.5 | ND | 2.8 | 72.2 | 321.7 | 304 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| OCDF | 15.7 | ND | 11.4 | 69.2 | 639.2 | 1,024.3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total TCDD | 0.7 | ND | ND | ND | 0.4 | ND | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total PeCDD | ND | ND | ND | ND | 2 | ND | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total HxCDD | 1.2 | ND | ND | ND | 1.8 | ND | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total HpCDD | 5.6 | 5.4 | 11.6 | 11 | 3 | 13.5 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total OCDD | 31.1 | 24.7 | 30.3 | 26.9 | 14.9 | 32.3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total TCDF | 6,376.6 | 713 | 1,289.4 | 5,402.3 | 15,785.7 | 16,340 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total PeCDF | 2,402.4 | 136.5 | 770.8 | 2,153.7 | 11,654.6 | 21,164 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total HxCDF | 804.8 | 5.1 | 143.6 | 2,213.8 | 4,455.8 | 7,630.2 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total HpCDF | 108.3 | 0.8 | 19.5 | 478.8 | 1,517 | 2,522.3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total OCDF | 15.7 | ND | 11.4 | 69.2 | 639.2 | 1,024.3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total CDD/CDF ^e | 9,746.4 | 885.5 | 2,276.61 | 10,355.7 | 34,074.4 | 48,726.5 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total I-TEQ _{DF} ^e | 407.2 | 11.3 | | 409.6 | 1,439.2 | 2,179 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total TEQ _{DF} -WHO ₉₈ ^e | 407.2 | 11.3 | | 409.5 | 1,439 | 2,178 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

^aSource: Malisch (1994).^bSource: Hagenmaier (1987).^cSource: Brown et al. (1988).^dSource: Bowes (1975b).^eCalculated assuming nondetect values were zero.

ND = Not detected

-- = No information given

Table 8-14. Reported CDD/CDF concentrations in wastes from polyvinyl chloride (PVC) manufacture (µg/kg)

| Congener/congener group | F024 waste | K019 waste | K020 waste |
|--|-------------------|-------------------|-------------------|
| 2,3,7,8-TCDD | 0.37 | 260 | 0.06 |
| 1,2,3,7,8-PeCDD | 0.14 | 890 | 0.05 |
| 1,2,3,4,7,8-HxCDD | 0.3 | 260 | 0.08 |
| 1,2,3,6,7,8-HxCDD | 0.14 | 330 | 0.06 |
| 1,2,3,7,8,9-HxCDD | 0.11 | 620 | 0.07 |
| 1,2,3,4,6,7,8-HpCDD | 4.2 | 920 | 0.89 |
| OCDD | 15 | 1,060 | 3 |
| 2,3,7,8-TCDF | 0.91 | 680 | 0.44 |
| 1,2,3,7,8-PeCDF | 9.5 | 975 | 1.8 |
| 2,3,4,7,8-PeCDF | 1.6 | 1,050 | 0.58 |
| 1,2,3,4,7,8-HxCDF | 110 | 10,100 | 11 |
| 1,2,3,6,7,8-HxCDF | 24 | 9,760 | 2.4 |
| 1,2,3,7,8,9-HxCDF | 9.5 | 21,800 | 1.3 |
| 2,3,4,6,7,8-HxCDF | 3.1 | 930 | 0.89 |
| 1,2,3,4,6,7,8-HpCDF | 250 | 13,400 | 38 |
| 1,2,3,4,7,8,9-HpCDF | 51 | 1,340 | 6 |
| OCDF | 390 | 43,500 | 650 |
| Total 2,3,7,8-CDD | 20.3 | 4,340 | 4.21 |
| Total 2,3,7,8-CDF | 849.6 | 103,535 | 712.4 |
| Total I-TEQ _{DF} | 20 | 5,928 | 3.2 |
| Total TEQ _{DF} -WHO ₉₈ | 19.7 | 6,333 | 2.6 |
| Total TCDD | 3.1 | 1,230 | 1.9 |
| Total PeCDD | 3.6 | 3,540 | 1.7 |
| Total HxCDD | 1.3 | 3,950 | ^a |
| Total HpCDD | 5 | 1,270 | 1.7 |
| Total OCDD | 15 | 1,060 | 3 |
| Total TCDF | 15 | 20,600 | 6 |
| Total PeCDF | 65 | 45,300 | 11 |
| Total HxCDF | 300 | 63,700 | 27 |
| Total HpCDF | 450 | 16,600 | 58 |
| Total OCDF | 390 | 43,500 | 650 |
| Total CDD/CDF | 1,248 | 200,750 | 760.3 |

^aCongener group concentration reported in source is not consistent with reported congener concentrations.

Source: Stringer et al. (1995).

Table 8-15. CDD/CDF measurements in treated wastewater and wastewater solids from U.S. EDC/VCM/PVC manufacturers

| Congener/congener groups | Treated wastewater | | | | | | Wastewater solids | | | | | |
|---|-------------------------|--|------|-------------------------|--|------|-------------------------|---|-----------|-------------------------|---|------|
| | PVC-only facilities | | | EDC/VCM/PVC facilities | | | EDC/VCM/PVC facilities | | | PVC-only facilities | | |
| | No. detects/ samples | Concentration range ^a (ng/L) | | No. detects/ samples | Concentration range ^a (ng/L) | | No. detects/ samples | Concentration range ^{b,c} (ng/kg) | | No. detects/ samples | Concentration range ^{b,c} (ng/kg) | |
| | | Min. | Max. | | Min. | Max. | | Min. | Max. | | Min. | Max. |
| 2,3,7,8-TCDD | 0/6 | ND | ND | 0/4 | ND | ND | 4/8 | ND | 109 | 1/2 | ND | 2 |
| 1,2,3,7,8-PeCDD | 0/6 | ND | ND | 0/4 | ND | ND | 3/8 | ND | 320 | 0/2 | ND | ND |
| 1,2,3,4,7,8-HxCDD | 0/6 | ND | ND | 0/4 | ND | ND | 4/8 | ND | 455 | 1/2 | ND | 3.2 |
| 1,2,3,6,7,8-HxCDD | 0/6 | ND | ND | 0/4 | ND | ND | 7/8 | ND | 520 | 1/2 | ND | 2.3 |
| 1,2,3,7,8,9-HxCDD | 0/6 | ND | ND | 0/4 | ND | ND | 6/8 | ND | 645 | 1/2 | ND | 2.4 |
| 1,2,3,4,6,7,8-HpCDD | 2/6 | ND | 26 | 1/4 | ND | 14 | 8/8 | 74 | 3,230 | 2/2 | 28 | 35 |
| OCDD | 1/6 | ND | 260 | 1/4 | ND | 130 | 8/8 | 390 | 9,700 | 2/2 | 200 | 640 |
| 2,3,7,8-TCDF | 0/6 | ND | ND | 0/4 | ND | ND | 8/8 | 18 | 460 | 0/2 | ND | ND |
| 1,2,3,7,8-PeCDF | 0/6 | ND | ND | 0/4 | ND | ND | 8/8 | 36 | 1,500 | 0/2 | ND | ND |
| 2,3,4,7,8-PeCDF | 0/6 | ND | ND | 0/4 | ND | ND | 8/8 | 50 | 1,750 | 0/2 | ND | ND |
| 1,2,3,4,7,8-HxCDF | 1/6 | ND | 5.8 | 0/4 | ND | ND | 8/8 | 180 | 7,550 | 1/2 | ND | 3.6 |
| 1,2,3,6,7,8-HxCDF | 1/6 | ND | 3.8 | 0/4 | ND | ND | 8/8 | 74 | 3,650 | 1/2 | ND | 2.4 |
| 1,2,3,7,8,9-HxCDF | 0/6 | ND | ND | 0/4 | ND | ND | 8/8 | 78 | 2,800 | 1/2 | ND | 3.8 |
| 2,3,4,6,7,8-HxCDF | 1/6 | ND | 6.1 | 1/4 | ND | 6.5 | 7/8 | ND | 425 | 0/2 | ND | ND |
| 1,2,3,4,6,7,8-HpCDF | 1/6 | ND | 26 | 3/4 | ND | 78 | 8/8 | 570 | 20,600 | 1/2 | 9.7 | 12 |
| 1,2,3,4,7,8,9-HpCDF | 1/6 | ND | 6.2 | 2/4 | ND | 20 | 7/8 | ND | 12,000 | 1/2 | ND | 2 |
| OCDF | 2/6 | ND | 33 | 4/4 | ND | 900 | 8/8 | 1,800 | 4,200,000 | 2/2 | 39 | 43 |
| Mean I-TEQ _{DF} (nondetect = 0) | | 0.42 | | | 0.88 | | | 1,680 | | | 1.9 | |
| Mean I-TEQ _{DF} (nondetect = ½ DL) | | | 4.4 | | | 4.7 | | | 1,680 | | | 3.6 |
| Total TCDD | 0/6 | ND | ND | 0/4 | ND | ND | 6/8 | ND | 730 | 1/2 | ND | 6.3 |
| Total PeCDD | 0/6 | ND | ND | 0/4 | ND | ND | 5/8 | ND | 1,630 | 1/2 | ND | 3.3 |
| Total HxCDD | 0/6 | ND | ND | 0/4 | ND | ND | 7/8 | ND | 3,915 | 1/2 | ND | 14 |
| Total HpCDD | 2/6 | ND | 48 | 1/4 | ND | 22 | 8/8 | 74 | 5,300 | 2/2 | 58 | 64 |
| Total OCDD | 1/6 | ND | 260 | 1/4 | ND | 130 | 8/8 | 390 | 9,700 | 2/2 | 200 | 640 |
| Total TCDF | 0/6 | ND | ND | 0/4 | ND | ND | 8/8 | 210 | 9,800 | 1/2 | ND | 4.8 |
| Total PeCDF | 0/6 | ND | ND | 0/4 | ND | ND | 8/8 | 380 | 18,000 | 1/2 | ND | 4 |
| Total HxCDF | 1/6 | ND | 30 | 1/4 | ND | 14 | 8/8 | 750 | 31,000 | 2/2 | 1.5 | 11 |
| Total HpCDF | 1/6 | ND | 49 | 3/4 | ND | 140 | 8/8 | 880 | 39,400 | 2/2 | 11 | 18 |
| Total OCDF | 2/6 | ND | 33 | 4/4 | ND | 900 | 8/8 | 1,800 | 4,200,000 | 2/2 | 39 | 43 |

^aMethod detection limits for individual samples were less than 10 pg/L for all congeners and congener groups except OCDD and OCDF, which had MDLs less than 50 pg/L.

^bDry-weight basis.

^cMethods detection limits for all congeners were less than 150 ng/kg and usually were less than 10 ng/kg.

Table 8-15. CDD/CDF measurements in treated wastewater and wastewater solids from U.S. EDC/VCM/PVC manufacturers (continued)

Source: Vinyl Institute (1998).

EDC = Ethylene dichloride

VCM = Vinyl chloride monomer

PVC = Polyvinyl chloride

DL = Detection limit

ND = Not detected

Table 8-16. Emissions data for wastewater from PVC/EDC/VCM manufacturing facilities

| Congener | Annual Release to Water (g/yr) | | | | | | | |
|--|--------------------------------|--------------------------------|--------------------------------|---------------------------|-----------------------------|-----------------------------|---------------------------|------------------------------------|
| | Dow Chemical Freeport, TX | Dow Chemical Plaquemine, LA | Georgia Gulf Plaquemine, LA | Occidental Convent, AL | Occidental Deer Park, TX | Occidental Ingleside, TX | Occidental LaPorte, TX | PPG Industries Lake Charles, LA |
| 2,3,7,8-TCDD | 0.00E+00 | 6.45E-02 | 6.90E-04 | 0.00E+00 | 0.00E+00 | 1.79E-02 | 0.00E+00 | 0.00E+00 |
| 1,2,3,7,8-PeCDD | 0.00E+00 | 1.19E-01 | 3.55E-03 | 0.00E+00 | 0.00E+00 | 9.25E-02 | 0.00E+00 | 2.37E-03 |
| 1,2,3,4,7,8-HxCDD | 5.64E-01 | 8.70E-01 | 3.98E-03 | 0.00E+00 | 2.20E-03 | 8.38E-02 | 0.00E+00 | 5.28E-03 |
| 1,2,3,6,7,8-HxCDD | 0.00E+00 | 0.00E+00 | 4.46E-03 | 0.00E+00 | 2.64E-03 | 8.55E-02 | 0.00E+00 | 6.27E-03 |
| 1,2,3,7,8,9-HxCDD | 3.52E-01 | 5.34E-01 | 5.00E-03 | 0.00E+00 | 2.45E-03 | 7.70E-02 | 0.00E+00 | 4.60E-03 |
| 1,2,3,4,6,7,8-HpCDD | 1.98E+01 | 2.90E+01 | 3.43E-02 | 3.26E-04 | 7.67E-02 | 9.50E-02 | 0.00E+00 | 4.03E-01 |
| OCDD | 1.23E+02 | 6.29E+02 | 1.18E-01 | 1.49E-01 | 1.19E+00 | 1.84E-01 | 5.18E-02 | 2.97E+00 |
| 2,3,7,8-TCDF | 2.77E+00 | 4.78E+00 | 7.61E-03 | 2.85E-04 | 5.08E-05 | 1.60E-02 | 0.00E+00 | 6.47E+00 |
| 1,2,3,7,8-PeCDF | 3.71E+00 | 3.77E+00 | 6.57E-03 | 6.00E-04 | 2.35E-03 | 8.91E-02 | 0.00E+00 | 1.43E+01 |
| 2,3,4,7,8-PeCDF | 1.67E+00 | 2.01E+00 | 2.11E-02 | 1.03E-04 | 3.68E-03 | 8.89E-02 | 0.00E+00 | 1.08E+01 |
| 1,2,3,4,7,8-HxCDF | 2.76E+01 | 2.22E+01 | 2.00E-02 | 1.72E-02 | 3.71E-02 | 8.83E-02 | 4.21E-02 | 1.23E+01 |
| 1,2,3,6,7,8-HxCDF | 0.00E+00 | 0.00E+00 | 1.41E-02 | 1.89E-04 | 2.77E-02 | 1.03E-01 | 0.00E+00 | 3.96E+00 |
| 1,2,3,7,8,9-HxCDF | 0.00E+00 | 1.08E+00 | 9.34E-03 | 0.00E+00 | 2.89E-02 | 9.80E-02 | 0.00E+00 | 3.23E+00 |
| 2,3,4,6,7,8-HxCDF | 6.08E+00 | 3.82E+00 | 7.89E-03 | 0.00E+00 | 1.44E-02 | 9.68E-02 | 0.00E+00 | 1.57E+00 |
| 1,2,3,4,6,7,8-HpCDF | 1.31E+02 | 1.64E+02 | 1.11E-01 | 2.51E-04 | 6.90E-01 | 1.00E-01 | 1.18E-01 | 4.41E+00 |
| 1,2,3,4,7,8,9-HpCDF | 1.93E+01 | 1.18E+01 | 2.41E-02 | 0.00E+00 | 2.61E-01 | 9.70E-02 | 3.18E-02 | 2.64E+00 |
| OCDF | 3.31E+02 | 3.81E+02 | 4.05E-01 | 3.55E-02 | 5.85E+00 | 1.85E-01 | 6.72E-01 | 1.21E+01 |
| | | | | | | | | |
| Total I-TEQ _{DF} | 6.91E+00 | 7.71E+00 | 2.28E-02 | 2.04E-03 | 3.08E-02 | 1.81E-01 | 6.43E-03 | 8.98E+00 |
| Total TEQ _{DF} -WHO ₉₈ | 6.50E+00 | 6.86E+00 | 2.41E-02 | 1.87E-03 | 2.45E-02 | 2.27E-01 | 5.78E-03 | 8.97E+00 |

03/04/05

8-72

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Table 8-17. Emissions data for wastewater from chlor-alkali production facilities

| Congener | Annual Release to Water (g/yr) | | | | | | | |
|--|--------------------------------|--------------------------------|-----------------------------|---------------------------------|-----------------------------|--------------------------|---------------------------------|-------------------------------|
| | Dow Chemical Midland, TX | Occidental Battleground, TX | Occidental Deer Park, TX | Occidental Delaware City, DE | Occidental Hahnville, LA | Occidental Mobile, AL | Occidental Muscle Shoals, AL | PPG Industries Natrium, WV |
| 2,3,7,8-TCDD | 0.00E+00 | 0.00E+00 | 2.40E-02 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 1,2,3,7,8-PeCDD | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 1,2,3,4,7,8-HxCDD | 1.72E-02 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 1,2,3,6,7,8-HxCDD | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 1,2,3,7,8,9-HxCDD | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 1,2,3,4,6,7,8-HpCDD | 5.44E-01 | 0.00E+00 | 7.79E-01 | 0.00E+00 | 1.33E-02 | 0.00E+00 | 0.00E+00 | 2.21E-01 |
| OCDD | 3.63E+00 | 4.83E-01 | 2.15E+01 | 4.09E-03 | 9.74E-02 | 1.15E-03 | 1.13E-09 | 3.13E+00 |
| 2,3,7,8-TCDF | 1.55E-02 | 0.00E+00 | 6.31E-01 | 1.02E-03 | 1.93E-01 | 2.88E-04 | 3.94E-08 | 6.38E-02 |
| 1,2,3,7,8-PeCDF | 0.00E+00 | 0.00E+00 | 1.20E+00 | 0.00E+00 | 8.97E-01 | 0.00E+00 | 1.33E-07 | 6.23E-02 |
| 2,3,4,7,8-PeCDF | 8.64E-03 | 0.00E+00 | 2.07E-01 | 0.00E+00 | 8.51E-01 | 0.00E+00 | 7.99E-08 | 3.29E-01 |
| 1,2,3,4,7,8-HxCDF | 5.90E-02 | 0.00E+00 | 2.11E+00 | 0.00E+00 | 2.96E+00 | 0.00E+00 | 1.85E-07 | 1.11E-01 |
| 1,2,3,6,7,8-HxCDF | 0.00E+00 | 0.00E+00 | 3.80E-01 | 0.00E+00 | 1.18E+00 | 0.00E+00 | 9.76E-08 | 0.00E+00 |
| 1,2,3,7,8,9-HxCDF | 0.00E+00 | 0.00E+00 | 2.03E-03 | 0.00E+00 | 6.31E-01 | 0.00E+00 | 2.29E-08 | 0.00E+00 |
| 2,3,4,6,7,8-HxCDF | 3.96E-02 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 6.00E-01 | 0.00E+00 | 3.28E-08 | 0.00E+00 |
| 1,2,3,4,6,7,8-HpCDD | 8.81E-01 | 0.00E+00 | 5.91E-01 | 2.31E-03 | 4.47E+00 | 6.49E-04 | 1.32E-07 | 1.54E-01 |
| 1,2,3,4,7,8,9-HpCDD | 1.45E-02 | 0.00E+00 | 5.66E-03 | 0.00E+00 | 6.89E-01 | 0.00E+00 | 6.30E-08 | 0.00E+00 |
| OCDF | 1.25E+00 | 0.00E+00 | 4.88E+00 | 0.00E+00 | 1.75E+00 | 0.00E+00 | 1.34E-07 | 6.60E-01 |
| | | | | | | | | |
| Total I-TEQ _{DF} | 3.67E-02 | 4.83E-04 | 5.40E-01 | 1.30E-04 | 1.08E+00 | 3.64E-05 | 8.65E-08 | 1.93E-01 |
| Total TEQ _{DF} -WHO ₉₈ | 3.23E-02 | 4.83E-05 | 5.16E-01 | 1.26E-04 | 1.08E+00 | 3.54E-05 | 8.64E-08 | 1.89E-01 |

Source: Chlorine Chemistry Council CDD/CDF Data Validation Project (2004).

Table 8-18. Congener-Specific land releases for PVC/EDC/VCM manufacturing facilities

| Congener | Annual Release to Land (g/yr) |
|--|--------------------------------|
| | Georgia Gulf Plaquemine, LA |
| 2,3,7,8-TCDD | 4.19E-03 |
| 1,2,3,7,8-PeCDD | 3.91E-02 |
| 1,2,3,4,7,8-HxCDD | 1.23E-01 |
| 1,2,3,6,7,8-HxCDD | 1.22E-01 |
| 1,2,3,7,8,9-HxCDD | 7.77E-02 |
| 1,2,3,4,6,7,8-HpCDD | 1.71E+00 |
| OCDD | 8.64E+00 |
| 2,3,7,8-TCDF | 7.65E-02 |
| 1,2,3,7,8-PeCDF | 3.54E-01 |
| 2,3,4,7,8-PeCDF | 3.70E-01 |
| 1,2,3,4,7,8-HxCDF | 2.69E+00 |
| 1,2,3,6,7,8-HxCDF | 2.11E+00 |
| 1,2,3,7,8,9-HxCDF | 1.54E+00 |
| 2,3,4,6,7,8-HxCDF | 5.95E-01 |
| 1,2,3,4,6,7,8-HpCDD | 2.81E+01 |
| 1,2,3,4,7,8,9-HpCDD | 6.54E+00 |
| OCDF | 1.18E+02 |
| | |
| Total I-TEQ _{DF} | 1.45E+00 |
| Total TEQ _{DF} -WHO ₉₈ | 1.36E+00 |

Source: Chlorine Chemistry Council CDD/CDF Data Validation Project (2004).

Table 8-19. Congener-specific air emissions for PVC/EDC/VCM manufacturing facilities

| Congener | Annual Release to Air (g/yr) | | | | | | | |
|--|------------------------------|--------------------------------|--------------------------------|---------------------------|-----------------------------|-----------------------------|---------------------------|------------------------------------|
| | Dow Chemical Freeport, TX | Dow Chemical Plaquemine, LA | Georgia Gulf Plaquemine, LA | Occidental Convent, AL | Occidental Deer Park, TX | Occidental Ingleside, TX | Occidental LaPorte, TX | PPG Industries Lake Charles, LA |
| 2,3,7,8-TCDD | 1.42E-02 | 6.11E-05 | 1.64E-03 | 4.53E-03 | 0.00E+00 | 5.96E-03 | 0.00E+00 | 2.28E-04 |
| 1,2,3,7,8-PeCDD | 1.98E-01 | 4.98E-03 | 2.68E-03 | 1.03E-02 | 9.76E-03 | 3.38E-02 | 6.81E-03 | 2.20E-04 |
| 1,2,3,4,7,8-HxCDD | 1.01E+00 | 2.80E-02 | 2.83E-03 | 3.79E-03 | 4.72E-02 | 1.07E-01 | 9.37E-03 | 1.89E-03 |
| 1,2,3,6,7,8-HxCDD | 0.00E+00 | 0.00E+00 | 2.34E-03 | 9.96E-03 | 3.27E-02 | 1.22E-01 | 1.65E-02 | 7.61E-04 |
| 1,2,3,7,8,9-HxCDD | 3.86E-01 | 1.18E-02 | 1.26E-03 | 4.84E-03 | 5.64E-02 | 8.99E-02 | 9.83E-03 | 4.50E-04 |
| 1,2,3,4,6,7,8-HpCDD | 3.73E+00 | 1.02E-01 | 1.64E-02 | 5.68E-03 | 1.37E+00 | 1.58E+00 | 1.51E-01 | 6.09E-03 |
| OCDD | 9.46E+00 | 2.65E-01 | 1.24E-01 | 4.74E-03 | 1.35E+01 | 9.51E+00 | 4.75E-01 | 3.95E-02 |
| 2,3,7,8-TCDF | 1.26E+00 | 2.63E-02 | 9.20E-02 | 1.52E-02 | 5.71E-02 | 4.38E-02 | 7.78E-03 | 1.29E-02 |
| 1,2,3,7,8-PeCDF | 1.80E+00 | 3.84E-02 | 7.21E-02 | 1.74E-02 | 1.21E-01 | 3.54E-01 | 2.42E-02 | 1.28E-02 |
| 2,3,4,7,8-PeCDF | 1.28E+00 | 3.15E-02 | 3.46E-02 | 9.22E-03 | 1.42E-01 | 3.71E-01 | 2.53E-02 | 8.71E-03 |
| 1,2,3,4,7,8-HxCDF | 1.20E+01 | 3.96E-01 | 1.71E-01 | 1.44E-02 | 1.38E+00 | 3.58E+00 | 4.13E-02 | 4.81E-02 |
| 1,2,3,6,7,8-HxCDF | 0.00E+00 | 0.00E+00 | 7.09E-02 | 8.52E-03 | 5.82E-01 | 3.38E+00 | 3.62E-02 | 2.50E-02 |
| 1,2,3,7,8,9-HxCDF | 3.43E-01 | 4.77E-03 | 4.17E-02 | 3.15E-03 | 5.55E-01 | 7.73E-01 | 8.02E-03 | 9.68E-03 |
| 2,3,4,6,7,8-HxCDF | 2.50E+00 | 4.80E-02 | 1.33E-02 | 1.33E-03 | 5.56E-02 | 1.94E+00 | 4.09E-02 | 8.79E-03 |
| 1,2,3,4,6,7,8-HpCDD | 3.23E+01 | 1.47E+00 | 3.17E-01 | 1.96E-02 | 1.19E+01 | 2.57E+01 | 2.49E-01 | 2.77E-01 |
| 1,2,3,4,7,8,9-HpCDD | 5.34E+00 | 9.81E-02 | 3.43E-02 | 2.36E-03 | 2.32E+00 | 5.13E+00 | 2.31E-02 | 4.12E-02 |
| OCDF | 6.69E+01 | 3.21E+00 | 1.01E+00 | 1.53E-02 | 5.28E+01 | 4.69E+01 | 2.31E-01 | 7.50E-01 |
| | | | | | | | | |
| Total I-TEQ _{DF} | 3.08E+00 | 9.19E-02 | 6.82E-02 | 2.16E-02 | 5.81E-01 | 1.61E+00 | 3.92E-02 | 2.01E-02 |
| Total TEQ _{DF} -WHO ₉₈ | 3.11E+00 | 9.12E-02 | 6.85E-02 | 2.67E-02 | 5.26E-01 | 1.58E+00 | 4.19E-02 | 1.95E-02 |

Source: Chlorine Chemistry Council CDD/CDF Data Validation Project (2004).

Table 8-20. Congener-specific air emissions for chlor-alkali production facilities

| Congener | Annual Release to Air (g/yr) | |
|--|------------------------------|-------------------------------|
| | Dow Chemical Midland, TX | PPG Industries Natrium, WV |
| 2,3,7,8-TCDD | 2.65E-02 | 2.81E-03 |
| 1,2,3,7,8-PeCDD | 3.86E-03 | 0.00E+00 |
| 1,2,3,4,7,8-HxCDD | 8.05E-03 | 0.00E+00 |
| 1,2,3,6,7,8-HxCDD | 0.00E+00 | 2.01E-03 |
| 1,2,3,7,8,9-HxCDD | 3.32E-03 | 2.01E-03 |
| 1,2,3,4,6,7,8-HpCDD | 2.03E-02 | 8.67E-02 |
| OCDD | 8.63E-02 | 2.08E-01 |
| 2,3,7,8-TCDF | 2.28E-02 | 4.38E-02 |
| 1,2,3,7,8-PeCDF | 9.10E-03 | 3.21E-03 |
| 2,3,4,7,8-PeCDF | 7.63E-03 | 3.01E-02 |
| 1,2,3,4,7,8-HxCDF | 6.61E-02 | 4.42E-02 |
| 1,2,3,6,7,8-HxCDF | 0.00E+00 | 6.42E-03 |
| 1,2,3,7,8,9-HxCDF | 1.82E-03 | 6.02E-03 |
| 2,3,4,6,7,8-HxCDF | 9.03E-03 | 2.17E-02 |
| 1,2,3,4,6,7,8-HpCDD | 1.48E-01 | 1.42E-01 |
| 1,2,3,4,7,8,9-HpCDD | 2.78E-02 | 3.89E-02 |
| OCDF | 2.25E-01 | 6.38E-02 |
| | | |
| Total I-TEQ _{DF} | 4.61E-02 | 3.36E-02 |
| Total TEQ _{DF} -WHO ₉₈ | 4.77E-02 | 3.33E-02 |

Source: Chlorine Chemistry Council CDD/CDF Data Validation Project (2004).

Table 8-21. CDD/CDF concentrations in products from U.S. EDC/VCM/PVC manufacturers

| Congener/congener group | Suspension and mass PVC resins | | | Dispersion PVC resins | | | EDC sold as product ^d | | |
|---|--------------------------------------|----------------------------|------|-------------------------------|----------------------------|------|----------------------------------|----------------------------|------|
| | No. detects/ samples ^a | Range ^b (ng/kg) | | No. of detects/ samples | Range ^c (ng/kg) | | No. detects/ samples | Range ^c (ng/kg) | |
| | | Min. | Max. | | Min. | Max. | | Min. | Max. |
| 2,3,7,8-TCDD | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| 1,2,3,7,8-PeCDD | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| 1,2,3,4,7,8-HxCDD | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| 1,2,3,6,7,8-HxCDD | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| 1,2,3,7,8,9-HxCDD | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| 1,2,3,4,6,7,8-HpCDD | 1/22 | ND | 0.64 | 1/6 | ND | 0.8 | 0/5 | ND | ND |
| OCDD | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| 2,3,7,8-TCDF | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| 1,2,3,7,8-PeCDF | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| 2,3,4,7,8-PeCDF | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| 1,2,3,4,7,8-HxCDF | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| 1,2,3,6,7,8-HxCDF | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| 1,2,3,7,8,9-HxCDF | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| 2,3,4,6,7,8-HxCDF | 1/22 | ND | 0.37 | 0/6 | ND | ND | 0/5 | ND | ND |
| 1,2,3,4,6,7,8-HpCDF | 0/22 | ND | ND | 0/6 | ND | ND | 1/5 | ND | 1.1 |
| 1,2,3,4,7,8,9-HpCDF | 0/22 | ND | ND | 0/6 | ND | ND | 1/5 | ND | 0.4 |
| OCDF | 0/22 | ND | ND | 2/6 | ND | 0.38 | 1/5 | ND | 11 |
| Mean I-TEQ _{DF} (nondetect = 0) | | 0.002 | | | 0.001 | | | 0.001 | |
| Mean I-TEQ _{DF} (nondetect = ½ DL) | | | 0.7 | | | 0.4 | | | 0.21 |
| Total TCDD | 0/22 | ND | ND | 1/6 | ND | 0.24 | 0/5 | ND | ND |
| Total PeCDD | 0/22 | ND | ND | 1/6 | ND | 0.32 | 0/5 | ND | ND |
| Total HxCDD | 0/22 | ND | ND | 5/6 | ND | 0.97 | 0/5 | ND | ND |
| Total HpCDD | 1/22 | ND | 0.64 | 1/6 | ND | 1.3 | 0/5 | ND | ND |
| Total OCDD | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| Total TCDF | 0/22 | ND | ND | 0/6 | ND | ND | 0/5 | ND | ND |
| Total PeCDF | 0/22 | ND | ND | 1/6 | ND | 0.3 | 0/5 | ND | ND |
| Total HxCDF | 1/22 | ND | 0.37 | 0/6 | ND | ND | 0/5 | ND | ND |
| Total HpCDF | 0/22 | ND | ND | 0/6 | ND | ND | 1/5 | ND | 2.02 |
| Total OCDF | 0/22 | ND | ND | 2/6 | ND | 0.38 | 1/5 | ND | 11 |

^aTwo of these 22 samples were duplicate samples from two sites. The results were averaged and treated as one sample for each site.

^bMethod detection limits (MDLs) for individual samples were less than 2 ng/kg for all congeners and congener groups except OCDD and OCDF, which had MDLs less than 6 ng/kg.

03/04/05

^cMDLs for individual samples were less than 2 ng/kg for all congeners and congener groups except OCDD and OCDF, which had MDLs less than 4 ng/kg.

^d“Sales” EDC is defined as EDC sold commercially for non-VCM uses or exported from the United States.

^eMDLs were less than 1 ng/kg for all congeners in all samples.

DL = Detection limit

ND = Not detected

Source: Vinyl Institute (1998).

8-78

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Table 8-22. CDD/CDF concentrations in samples of dioxazine dyes and pigments (µg/kg) (Canada)

| Congener/congener group | Blue 106 | | | Blue 108 | Violet 23 | | | | | |
|---|----------|----------|----------|----------|-----------|----------|----------|----------|----------|----------|
| 2,3,7,8-TCDD | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) |
| 1,2,3,7,8-PeCDD | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) |
| 1,2,3,4,7,8-HxCDD | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1,2,3,6,7,8-HxCDD | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) |
| 1,2,3,7,8,9-HxCDD | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) |
| 1,2,3,4,6,7,8-HpCDD | 31 | 6 | 9 | ND (0.3) | 9 | 1 | 16 | 10 | 2 | 4 |
| OCDD | 41,953 | 28,523 | 18,066 | 23 | 7,180 | 806 | 11,022 | 7,929 | 1,627 | 1,420 |
| 2,3,7,8-TCDF | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) |
| 1,2,3,7,8-PeCDF | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | 0.5 | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) |
| 2,3,4,7,8-PeCDF | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) |
| 1,2,3,4,7,8-HxCDF | 12 | 2 | 2 | ND (0.3) | 76 | 4 | 39 | 31 | 9 | 7 |
| 1,2,3,6,7,8-HxCDF ^a | | | | | | | | | | |
| 1,2,3,7,8,9-HxCDF | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2,3,4,6,7,8-HxCDF | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) |
| 1,2,3,4,6,7,8-HpCDF | 50 | 10 | 14 | 9 | 13 | 10 | 11 | 4 | 1 | 12 |
| 1,2,3,4,7,8,9-HpCDF | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| OCDF | 12,463 | 1,447 | 1,006 | 11 | 941 | 125 | 3,749 | 1,556 | 147 | 425 |
| Total 2,3,7,8-CDD | 41,984 | 28,529 | 18,075 | 23 | 7,189 | 807 | 11,038 | 7,939 | 1,629 | 1,424 |
| Total 2,3,7,8-CDF | 12,525 | 1,459 | 1,022 | 20 | 1,031 | 139 | 3,799 | 1,591 | 157 | 444 |
| Total I-TEQ _{DF} ^b | 56.4 | 30.3 | 19.5 | 0.1 | 16.0 | 1.4 | 18.9 | 12.7 | 2.7 | 2.7 |
| Total TEQ _{DF} -WHO ₉₈ ^b | 7.45 | 3.4 | 2.3 | 0.1 | 8.7 | 0.6 | 5.6 | 4.2 | 1.1 | 1 |
| Total TCDD | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) |
| Total PeCDD | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) |
| Total HxCDD | ND (0.3) | ND (0.3) | ND (0.3) | 1 | 21 | 2 | 7 | ND (0.3) | ND (0.3) | 1 |
| Total HpCDD | 34 | 8 | 12 | ND (0.3) | 30 | 5 | 36 | 11 | 2 | 6 |
| Total OCDD | 41,953 | 28,523 | 18,066 | 23 | 7,180 | 806 | 11,022 | 7,929 | 1,627 | 1,420 |
| Total TCDF | ND (0.3) | 0.3 | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | 0.4 | ND (0.3) |
| Total PeCDF | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | 0.5 | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) | ND (0.3) |
| Total HxCDF | 12 | 2 | 2 | ND (0.3) | 76 | 5 | 39 | 31 | 9 | 7 |
| Total HpCDF | 71 | 32 | 26 | 12 | 26 | 14 | 29 | 13 | 2 | 21 |
| Total OCDF | 12,463 | 1,447 | 1,006 | 11 | 941 | 125 | 3,749 | 1,556 | 147 | 425 |
| Total CDD/CDF ^b | 54,533 | 30,012 | 19,112 | 47 | 8,275 | 957 | 14,882 | 9,540 | 1,787 | 1,880 |

^aResults listed for 1,2,3,4,7,8-HxCDF include concentrations for 1,2,3,6,7,8-HxCDF.^bCalculations assume nondetected values are equal to zero.

Table 8-22. CDD/CDF concentrations in samples of dioxazine dyes and pigments (µg/kg) (Canada) (continued)

ND = Not detected (value in parenthesis is the detection limit)

-- = Not reported

Source: Williams et al. (1992).

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Table 8-23. CDD/CDF concentrations in printing inks (ng/kg) (Germany)

| Congener/congener group | Rotogravure (2-color) | Rotogravure (4-color) | Offset (4-color) | Offset (4-color) |
|--|----------------------------------|----------------------------------|-----------------------------|-----------------------------|
| 2,3,7,8-TCDD | ND (1) | ND (1.5) | ND (2) | ND (2) |
| 1,2,3,7,8-PeCDD | 8 | ND (4) | 15 | 6 |
| 1,2,3,4,7,8-HxCDD | 19 | ND (5) | 16 | 11 |
| 1,2,3,6,7,8-HxCDD | 325 | 310 | 82 | 21 |
| 1,2,3,7,8,9-HxCDD | 155 | 105 | 42 | 14 |
| 1,2,3,4,6,7,8-HpCDD | 2,770 | 1,630 | 540 | 240 |
| OCDD | 5,810 | 2,350 | 890 | 230 |
| 2,3,7,8-TCDF | 2.5 | 14 | 7 | 7 |
| 1,2,3,7,8-PeCDF | ND (2) | ND (4) | ND (4) | ND (3) |
| 2,3,4,7,8-PeCDF | ND (2) | ND (4) | ND (4) | ND (3) |
| 1,2,3,4,7,8-HxCDF | 4 | 7 | 27 | 35 |
| 1,2,3,6,7,8-HxCDF | ND (3) | ND (5) | ND (5) | ND (5) |
| 1,2,3,7,8,9-HxCDF | ND (3) | ND (5) | ND (5) | ND (5) |
| 2,3,4,6,7,8-HxCDF | ND (3) | ND (5) | ND (5) | ND (5) |
| 1,2,3,4,6,7,8-HpCDF | 40 | 14 | 315 | 42 |
| 1,2,3,4,7,8,9-HpCDF | ND (4) | ND (7) | 11 | ND (6) |
| OCDF | 129 | ND (10) | 960 | 165 |
| Total 2,3,7,8-CDD | 9,087 | 4,395 | 1,585 | 522 |
| Total 2,3,7,8-CDF | 175.5 | 35 | 1,320 | 249 |
| Total I-TEQ _{DF} ^a | 88.6 | 62.4 | 35.4 | 15 |
| Total TEQ _{DF} -WHO ₉₈ | 87.2 | 60.3 | 41.2 | 18 |
| Total TCDD | 4 | ND (2) | 77 | 38 |
| Total PeCDD | 58 | 145 | 35 | 25 |
| Total HxCDD | 2,679 | 2,485 | 660 | 246 |
| Total HpCDD | 5,630 | 3,460 | 1,100 | 445 |
| Total OCDD | 5,810 | 2,350 | 890 | 230 |
| Total TCDF | 5.5 | 28 | 90 | 35 |
| Total PeCDF | 13 | ND (4) | 340 | 110 |
| Total HxCDF | 29 | 45 | 95 | 94 |
| Total HpCDF | 64 | 14 | 566 | 63 |
| Total OCDF | 129 | ND (10) | 960 | 165 |
| Total CDD/CDF | 14,422 | 8,527 | 4,813 | 1,451 |

^aCalculations assume nondetect values were zero.

ND = Not detected (value in parenthesis is the detection limit)

-- = Not reported

Source: Santl et al. (1994).

Table 8-24. Chemicals requiring Toxic Substances Control Act Section 4 testing under the dioxin/furan rule

| Currently manufactured or imported as of June 5, 1987 | |
|--|---|
| CAS No. | Chemical name |
| 79-94-7 | Tetrabromobisphenol-A |
| 118-75-2 | 2,3,5,6-Tetrachloro-2,5-cyclohexadiene-1,4-dione |
| 118-79-6 | 2,4,6-Tribromophenol |
| 120-83-2 | 2,4-Dichlorophenol |
| 1163-19-5 | Decabromodiphenyloxide |
| 4162-45-2 | Tetrabromobisphenol-A-bisethoxylate |
| 21850-44-2 | Tetrabromobisphenol-A-bis-2,3-dibromopropylether ^a |
| 25327-89-3 | Allyl ether of tetrabromobisphenol-A |
| 32534-81-9 | Pentabromodiphenyloxide |
| 32536-52-0 | Octabromodiphenyloxide |
| 37853-59-1 | 1,2-Bis(tribromophenoxy)-ethane |
| 55205-38-4 | Tetrabromobisphenol-A-diacrylate ^a |
| Not currently manufactured or imported as of June 5, 1987^b | |
| CAS No. | Chemical name |
| 79-95-8 | Tetrachlorobisphenol-A |
| 87-10-5 | 3,4',5-Tribromosalicylanide |
| 87-65-0 | 2,6-Dichlorophenol |
| 95-77-2 | 3,4-Dichlorophenol |
| 95-95-4 | 2,4,5-Trichlorophenol |
| 99-28-5 | 2,6-Dibromo-4-nitrophenol |
| 120-36-5 | 2[2,4-(Dichlorophenoxy)]-propanoic acid |
| 320-72-9 | 3,5-Dichlorosalicyclic acid |
| 488-47-1 | Tetrabromocatechol |
| 576-24-9 | 2,3-Dichlorophenol |
| 583-78-8 | 2,5-Dichlorophenol |
| 608-71-9 | Pentabromophenol |
| 615-58-7 | 2,4-Dibromophenol |
| 933-75-5 | 2,3,6-Trichlorophenol |
| 1940-42-7 | 4-Bromo-2,5-dichlorophenol |
| 2577-72-2 | 3,5-Dibromosalicylanide |
| 3772-94-9 | Pentachlorophenyl laurate |
| 37853-61-5 | Bismethylether of tetrabromobisphenol-A |
| - | Alkylamine tetrachlorophenate |
| - | Tetrabromobisphenol-B |

^aNo longer manufactured in or imported into the United States (Cash, 1993).

^bAs of August 5, 1995, neither manufacture nor importation of any of these chemicals had resumed in the United States (Holderman, 1995).

Table 8-25. Congeners and limits of quantitation (LOQ) for which quantitation is required under the dioxin/furan test rule and pesticide Data Call-In

| Chlorinated dioxins and furans | Brominated dioxins and furans | LOQ (µg/kg) |
|---------------------------------------|--------------------------------------|--------------------|
| 2,3,7,8-TCDD | 2,3,7,8-TBDD | 0.1 |
| 1,2,3,7,8-PeCDD | 1,2,3,7,8-PeBDD | 0.5 |
| 1,2,3,4,7,8-HxCDD | 1,2,3,4,7,8-HxBDD | 2.5 |
| 1,2,3,6,7,8-HxCDD | 1,2,3,6,7,8-HxBDD | 2.5 |
| 1,2,3,7,8,9-HxCDD | 1,2,3,7,8,9-HxBDD | 2.5 |
| 1,2,3,4,6,7,8-HpCDD | 1,2,3,4,6,7,8-HpBDD | 100 |
| 2,3,7,8-TCDF | 2,3,7,8-TBDF | 1 |
| 1,2,3,7,8-PeCDF | 1,2,3,7,8-PeBDF | 5 |
| 2,3,4,7,8-PeCDF | 2,3,4,7,8-PeBDF | 5 |
| 1,2,3,4,7,8-HxCDF | 1,2,3,4,7,8-HxBDF | 25 |
| 1,2,3,6,7,8-HxCDF | 1,2,3,6,7,8-HxBDF | 25 |
| 1,2,3,7,8,9-HxCDF | 1,2,3,7,8,9-HxBDF | 25 |
| 2,3,4,6,7,8-HxCDF | 2,3,4,6,7,8-HxBDF | 25 |
| 1,2,3,4,6,7,8-HpCDF | 1,2,3,4,6,7,8-HpBDF | 1,000 |
| 1,2,3,4,7,8,9-HpCDF | 1,2,3,4,7,8,9-HpBDF | 1,000 |

Table 8-26. Precursor chemicals subject to reporting requirements under Toxic Substances Control Act Section 8(a)^a

| CAS No. | Chemical Name |
|----------|---|
| 85-22-3 | Pentabromoethylbenzene |
| 87-61-6 | 1,2,3-Trichlorobenzene |
| 87-84-3 | 1,2,3,4,5-Pentabromo-6-chlorocyclohexane |
| 89-61-2 | 1,4-Dichloro-2-nitrobenzene |
| 89-64-5 | 4-Chloro-2-nitrophenol |
| 89-69-0 | 2,4,5-Trichloronitrobenzene |
| 92-04-6 | 2-Chloro-4-phenylphenol |
| 97-74-6 | 4-Chloro-o-toloxo acetic acid |
| 94-81-5 | 4-(2-Methyl-4-chlorophenoxy) butyric acid |
| 95-50-1 | o-Dichlorobenzene |
| 95-56-7 | o-Bromophenol |
| 95-57-8 | o-Chlorophenol |
| 95-88-5 | 4-Chlororesorcinol |
| 95-94-3 | 1,2,4,5-Tetrachlorobenzene |
| 95-50-7 | 5-Chloro-2,4-dimethoxyaniline |
| 99-30-9 | 2,6-Dichloro-4-nitroaniline |
| 99-54-7 | 1,2-Dichloro-4-nitrobenzene |
| 106-46-7 | p-Dichlorobenzene |
| 108-70-3 | 1,3,5-Trichlorobenzene |
| 108-86-1 | Bromobenzene |
| 108-90-7 | Chlorobenzene |
| 117-18-0 | 1,2,4,5-Tetrachloro-3-nitrobenzene |
| 120-82-1 | 1,2,4-Trichlorobenzene |
| 348-51-6 | o-Chlorofluorobenzene |
| 350-30-1 | 3-Chloro-4-fluoronitrobenzene |
| 615-67-8 | Chlorohydroquinone |
| 626-39-1 | 1,3,5-Tribromobenzene |
| 827-94-1 | 2,6-Dibromo-4-nitroaniline |

^aDibromobenzene (CAS No. 106-37-6) was identified in the preamble to 52 FR 21412 as one of 29 precursor chemicals; however, it was inadvertently omitted from the regulatory text. Because the regulatory text identified only 28 chemicals, 28 chemicals appear in 40 CFR 766.38 and in this table.

Table 8-27. Results of analytical testing for dioxins and furans in the chemicals tested to date under Section 4 of the dioxin/furan test rule

| CAS number | Chemical name | No. of chemical companies that submitted data | No. of positive studies | Congeners detected (detection range in µg/kg) |
|-------------|--|---|-------------------------|---|
| 79-94-7 | Tetrabromobisphenol-A | 3 | 0 | a |
| 118-75-2 | 2,3,5,6-Tetrachloro-2,5-cyclohexadiene-1,4-dione (chloranil) | 6 | 5 | See Table 8-26 |
| 118-79-6 | 2,4,6-Tribromophenol | 1 | 0 | a |
| 120-83-2 | 2,4-Dichlorophenol | 1 | 0 | a |
| 1163-19-5 | Decabromodiphenyl oxide | 3 | 3 | 2,3,7,8-PeBDD (ND-0.1) 1,2,3,4,7,8/1,2,3,6,7,8-HxBDD (ND-0.5) 1,2,3,7,8,9-HxBDD (ND-0.76) 1,2,3,7,8-PeBDF (ND-0.7) 1,2,3,4,7,8/1,2,3,6,7,8-HxBDF (ND-0.8) 1,2,3,4,6,7,8-HpBDF (17-186) |
| 25327-89-3 | Allyl ether of tetrabromobisphenol-A | 1 | 0 | a |
| 32536-52-0 | Octabromodiphenyl oxide | 3 | 3 | 2,3,7,8-TBDD (ND-0.71) 1,2,3,7,8-PeBDD (ND-0.1) 2,3,7,8-TBDF (ND-12.6) 1,2,3,7,8-PeBDF (ND-6.3) 2,3,4,7,8-PeBDF (ND-83.1) 1,2,3,4,7,8/1,2,3,6,7,8-HxBDF (ND-67.8) 1,2,3,7,8,9-HxBDF (ND-56.0) 1,2,3,4,6,7,8-HpBDF (ND-330) |
| 378-53-59-1 | 1,2-Bis(tribromophenoxy)-ethane | 1 | 1 | 2,3,7,8-TBDF (ND-0.04) 1,2,3,4,7,8/1,2,3,6,7,8-HxBDF (ND-0.03) 1,2,3,4,6,7,8-HpBDF (ND-0.33) |
| 32534-81-9 | Pentabromodiphenyl oxide | 3 | 3 | 1,2,3,7,8-PeBDD (ND-5.9) 1,2,3,4,7,8/1,2,3,6,7,8-HxBDD (ND-6.8) 1,2,3,4,7,8/1,2,3,6,7,8-HxBDD (ND-6.8) 1,2,3,7,8,9-HxBDD (ND-0.02) 2,3,7,8-TBDF (ND-3.1) 1,2,3,7,8-PeBDF (0.7-10.2) 2,3,4,7,8-PeBDF (0.1-2.9) 1,2,3,4,7,8/1,2,3,6,7,8-HxBDF (15.6-61.2) 1,2,3,4,6,7,8-HpBDF (0.7-3.0) |
| 4162-45-2 | Tetrabromobisphenol-A-bisethoxylate | 1 | 0 | a |

^aNo 2,3,7,8-substituted dioxins and furans detected above the test rule target limits of quantitation (see Table 8-18).

Source: Holderman and Cramer (1995).

Table 8-28. CDD/CDF concentrations in chloranil and carbazole violet samples analyzed pursuant to the EPA dioxin/furan test rule (µg/kg)

| Congener | Chloranil | | | | Carbazole violet |
|---|------------|------------|------------|------------|------------------|
| | Importer 1 | Importer 2 | Importer 3 | Importer 4 | |
| 2,3,7,8-TCDD | ND (1) | ND (1) | ND (2) | ND (2) | ND (0.8) |
| 1,2,3,7,8-PeCDD | ND (2) | ND (2) | ND (5) | ND (6) | ND (0.5) |
| 1,2,3,4,7,8-HxCDD | ND (3) | ND (10) | ND (5) | ND (3) | ND (1.2) |
| 1,2,3,6,7,8-HxCDD | ND (3) | 75 | ND (5) | 6 | ND (1.2) |
| 1,2,3,7,8,9-HxCDD | ND (1) | 48 | ND (5) | 9 | ND (1.2) |
| 1,2,3,4,6,7,8-HpCDD | 110 | 8,200 | 390 | 2,300 | 28 |
| OCDD | 240,000 | 180,000 | 760,000 | 71,000 | 1,600 |
| 2,3,7,8-TCDF | ND (1) | ND (2) | ND (1) | ND (2) | ND (1.6) |
| 1,2,3,7,8-PeCDF | ND (1) | ND (1) | ND (3) | ND (5) | ND (0.9) |
| 2,3,4,7,8-PeCDF | ND (1) | ND (1) | ND (3) | ND (5) | ND (0.9) |
| 1,2,3,4,7,8-HxCDF | 35 | ND (860) | ND (4) | 5,600 | ND (20) |
| 1,2,3,6,7,8-HxCDF | ND (5) | ND (860) | ND (4) | ND (600) | ND (20) |
| 1,2,3,7,8,9-HxCDF | 6 | ND (680) | ND (4) | ND (600) | ND (20) |
| 2,3,4,6,7,8-HxCDF | ND (5) | ND (680) | ND (4) | ND (600) | ND (20) |
| 1,2,3,4,6,7,8-HpCDF | 33 | 240,000 | 36 | 230,000 | 15,000 |
| 1,2,3,4,7,8,9-HpCDF | ND (15) | ND (100) | ND (15) | ND (400) | ND (20) |
| OCDF | 18,000 | 200,000 | 50,000 | 110,000 | 59,000 |
| Total I-TEQ _{DF} ^a | 263 | 2,874 | 814 | 3,065 | 211 |
| Total TEQ _{DF} -WHO ₉₈ ^a | 31 | 2,532 | 85 | 2,903 | 156 |

^aCalculated assuming nondetect values are zero.

ND = Not detected (value in parenthesis is the minimum detection limit)

Source: Remmers et al. (1992).

Table 8-29. Status of first pesticide data call-in: pesticides suspected of having the potential to become contaminated with dioxins if synthesized under conditions favoring dioxin formation

| Shaughnessey code | Pesticide [active ingredient] | CAS number | Support withdrawn | Testing required |
|-------------------|---|------------|-------------------|------------------|
| 000014 | Dichlorodifluoromethane | 75-71-8 | Yes | -- |
| 008706 | O-(4-Bromo-2,5-dichlorophenyl) O,O-dimethyl phosphorothioate | 2104-96-3 | Yes | -- |
| 009105 | Dimethylamine 2,3,5-triodobenzoate | 17601-49-9 | Yes | -- |
| 012001 | Neburon | 555-37-3 | Yes | -- |
| 012101 | Crufomate | 299-86-5 | Yes | -- |
| 019201 | MCPB, 4-butyric acid [4-(2-Methyl-4-chlorophenoxy)butyric acid] | 94-81-5 | No | Yes |
| 019202 | MCPB, Na salt [Sodium 4-(2-methyl-4-chlorophenoxy)butyrate] | 6062-26-6 | No | No |
| 019401 | 4-Chlorophenoxyacetic acid | 122-88-3 | No | Yes |
| 025501 | Chloroxuron | 1982-47-4 | Yes | -- |
| 027401 | Dichlobenil | 1194-65-6 | No | Yes |
| 28201 | Propanil [3',4'-Dichloropropionanilide] | 709-98-8 | No | No |
| 028601 | Dichlofenthion [O-(2,4-Dichlorophenyl) O,O-diethyl phosphorothioate] | 97-17-6 | Yes | -- |
| 029201 | DDT [Dichloro diphenyl trichloroethane] | 50-29-3 | Yes | -- |
| 29601 | Dichlone [2,3-dichloro-1,4-naphthoquinone] | 117-80-6 | Yes | -- |
| 029902 | Ammonium chloramben [3-amino-2,5-dichlorobenzoic acid] | 1076-46-6 | Yes | -- |
| 029906 | Sodium chloramben [3-amino-2,5-dichlorobenzoic acid] | 1954-81-0 | Yes | -- |
| 030602 | Sodium 2-(2,4-dichlorophenoxy)ethyl sulfate | 136-78-7 | Yes | -- |
| 031301 | DCNA [2,6-Dichloro-4-nitroaniline] | 99-30-9 | No | Yes |
| 031503 | Potassium 2-(2-methyl-4-chlorophenoxy)propionate | 1929-86-8 | Yes | -- |
| 031516 | MCCP, DEA Salt [Diethanolamine 2-(2-methyl-4-chlorophenoxy)propionate] | 1432-14-0 | Yes | -- |
| 031563 | MCPP, IOE [Isooctyl 2-(2-methyl-4-chlorophenoxy)propionate] | 28473-03-2 | No | No |
| 034502 | Dicapthon [O-(2-chloro-4-nitrophenyl) O,O-dimethyl phosphorothioate] | 2463-84-5 | Yes | -- |
| 035502 | Monuron trichloroacetate [3-(4-chlorophenyl)-1,1-dimethylurea trichloroacetate] | 140-41-0 | Yes | -- |

Table 8-29. Status of first pesticide data call-in: pesticides suspected of having the potential to become contaminated with dioxins if synthesized under conditions favoring dioxin formation (continued)

| Shaughnessey code | Pesticide [active ingredient] | CAS number | Support withdrawn | Testing required |
|-------------------|--|---------------|-------------------|------------------|
| 35505 | Diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] | 330-54-1 | No | No |
| 35506 | Linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea] | 330-55-2 | No | No |
| 35901 | Metobromuron [3-(p-bromophenyl)-1-methoxy-1-methylurea] | 3060-89-7 | Yes | -- |
| 53501 | Methyl parathion [O,O-Dimethyl O-p-nitrophenyl phosphorothioate] | 298-00-0 | No | No |
| 55001 | Dichlorophene [Sodium 2,2'-methylenebis(4-chlorophenate)] | 97-23-4 | Yes | -- |
| 55005 | Dichlorophene, sodium salt [Sodium 2,2'-methylenebis(4-chlorophenate)] | 10254-48-5 | Yes | -- |
| 55201 | 1,2,4,5-Tetrachloro-3-nitrobenzene | 117-18-0 | Yes | -- |
| 57501 | Ethyl parathion [O,O-diethyl O-p-nitrophenyl phosphorothioate] | 56-38-2 | No | No |
| 58102 | Carbophenothion [S-(((p-chlorophenyl)thio)methyl) O,O-diethyl phosphorodithioate] | 786-19-6 | Yes | -- |
| 58301 | Ronnel [O,O-dimethyl O-(2,4,5-trichlorophenyl) phosphorothioate] | 229-84-3 | Yes | -- |
| 58802 | Mitin FF [Sodium 5-chloro-2-(4-chloro-2-(3-(3,4-dichlorophenyl)ureido)phenoxy) benzenesulfonate] | 3567-25-7 | No | No |
| 59401 | Orthodichlorobenzene | 95-50-1 | Yes | -- |
| 61501 | Paradichlorobenzene | 106-46-7 | No | No |
| 62201 | Chlorophene [2-Benzyl-4-chlorophenol] | 120-32-1 | No | No |
| 62202 | Potassium 2-benzyl-4-chlorophenate | 35471-49-9 | No | In review |
| 62203 | Sodium 2-benzyl-4-chlorophenate | 3184-65-4 | No | In review |
| 62204 | 2-Chlorophenol | 95-57-8 | Yes | -- |
| 62206 | 2-Chloro-4-phenylphenol | 92-04-6 | Yes | -- |
| 62207 | Potassium 2-chloro-4-phenylphenate | 18128-16-0 | Yes | -- |
| 62208 | 4-Chloro-2-phenylphenol | Not available | Yes | -- |
| 62209 | 4-Chloro-2-phenylphenol, potassium salt | 53404-21-0 | Yes | -- |
| 62210 | 6-Chloro-2-phenylphenol | 85-97-2 | Yes | -- |

Table 8-29. Status of first pesticide data call-in: pesticides suspected of having the potential to become contaminated with dioxins if synthesized under conditions favoring dioxin formation (continued)

| Shaughnessey code | Pesticide [active ingredient] | CAS number | Support withdrawn | Testing required |
|-------------------|---|---------------|-------------------|------------------|
| 62211 | 6-Chloro-2-phenylphenol, potassium salt | 18128-17-1 | Yes | -- |
| 62212 | 4-Chloro-2-phenylphenol, sodium salt | 10605-10-4 | Yes | -- |
| 62213 | 6-Chloro-2-phenylphenol, sodium salt | 10605-11-5 | Yes | -- |
| 62214 | 4 and 6-Chloro-2-phenylphenol, diethanolamine salt | 53537-63-6 | Yes | -- |
| 62215 | 2-Chloro-4-phenylphenol, sodium salt | 31366-97-9 | Yes | -- |
| 64202 | 4-Chloro-2-cyclopentylphenol | 13347-42-7 | Yes | -- |
| 64208 | Fentichlor [2,2'-Thiobis(4-chloro-6-methylphenol)] | 4418-66-0 | Yes | -- |
| 64209 | Fentichlor [2,2'-Thiobis(4-chlorophenol)] | 97-24-5 | Yes | -- |
| 64214 | 4-Chloro-2-cyclopentylphenol, potassium salt of | 35471-38-6 | Yes | -- |
| 64218 | 4-Chloro-2-cyclopentylphenol, sodium salt | 53404-20-9 | Yes | - |
| 67707 | Chlorophacinone | 3691-35-8 | No | No |
| 69105 | ADBAC [Alkyl* dimethyl benzyl ammonium chloride *(50% C14, 40% C12, 10% C16)] | 68424-85-1 | No | No |
| 69144 | ADBAC [Alkyl* dimethyl 3,4-dichlorobenzyl ammonium chloride *(61% C12, 23% C14, 11% C16, 5% C18)] | Not available | No | No |
| 77401 | Niclosamide [2-Aminoethanol salt of 2',5-dichloro-4'-nitrosalicylanilide] | 1420-04-8 | No | No |
| 77406 | 5-Chlorosalicylanilide | 4638-48-6 | Yes | -- |
| 78780 | 2-Methyl-4-isothiazolin-3-one | Not available | Yes | -- |
| 79202 | Tetradifon [4-chlorophenyl 2,4,5-trichlorophenyl sulfone] | 116-29-0 | Yes | -- |
| 79301 | Chloranil [tetrachloro-p-benzoquinone] | 118-75-2 | Yes | -- |
| 80403 | 6-Chlorothymol | 89-68-9 | Yes | -- |

Table 8-29. Status of first pesticide data call-in: pesticides suspected of having the potential to become contaminated with dioxins if synthesized under conditions favoring dioxin formation (continued)

| Shaughnessey code | Pesticide [active ingredient] | CAS number | Support withdrawn | Testing required |
|-------------------|---|---------------|-------------------|------------------|
| 80811 | Anilazine [2,4-Dichloro-6-(o-chloroanilino)-s-triazine] | 101-05-3 | Yes | -- |
| 81901 | Chlorothalonil [tetrachloroisophthalonitrile] | 1897-45-6 | No | Yes |
| 82602 | Sodium 2,3,6-Trichlorophenylacetate | 2439-00-1 | Yes | -- |
| 84101 | Chlorfenvinphos | 470-90-6 | Yes | -- |
| 84901 | O-(2-Chloro-1-(2,5-dichlorophenyl)vinyl) O,O-diethyl phosphorothioate | 1757-18-2 | Yes | -- |
| 86801 | PCMX [4-Chloro-3,5-xylene] | 88-04-0 | No | No |
| 97003 | Piperalin [3-(2-Methylpiperidino)propyl 3,4-dichlorobenzoate] | 3478-94-2 | No | No |
| 100601 | Fenamiphos | Not available | No | No |
| 101001 | p-Chlorophenyl diiodomethyl sulfone | 20018-12-6 | Yes | -- |
| 101101 | Metribuzin | 21087-64-9 | No | No |
| 104301 | BifenoX [methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate] | 42576-02-3 | Yes | -- |
| 106001 | Methazole [2-(3,4-dichlorophenyl)-4-methyl-1,2,4-oxadiazolidine-3,5-dione] | 20354-26-1 | Yes | -- |
| 108201 | Diflubenuron [N-(((4-chlorophenyl)amino)carbonyl)-2,6-difluorobenzamide] | 35367-38-5 | No | Yes |
| 109001 | Oxadiazon [2-tert-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)- delta 2 -1,3,4-oxadiazoline-5-one] | 19666-30-9 | No | Yes |
| 109301 | Fenvalerate | 51630-58-1 | No | In review |
| 109302 | Fluvalinate [N-2-Chloro-4-trifluoromethylphenyl-DL-valine (+-)-cyano(3-phenoxy-phenyl)methyl ester] | 69409-94-5 | No | No |
| 109801 | Iprodione [3-(3,5-Dichlorophenyl)-N-(1-methylethyl)-2,4-dioxo-1-imidazolidinecarboxamide (9CA)] | 36734-19-7 | No | No |
| 109901 | Triadimefon [1-(4-Chlorophenoxy)-3,3-dimethyl-1-(1H-1,2,4-triazol-1-yl)-2-butanone] | 43121-43-3 | No | No |

Table 8-29. Status of first pesticide data call-in: pesticides suspected of having the potential to become contaminated with dioxins if synthesized under conditions favoring dioxin formation (continued)

| Shaughnessey code | Pesticide [active ingredient] | CAS number | Support withdrawn | Testing required |
|-------------------|--|------------|-------------------|------------------|
| 110902 | Diclofop - methyl [methyl 2-(4-(2,4-dichlorophenoxy)phenoxy)propanoate] | 51338-27-3 | No | Yes |
| 111401 | Profenofos [O-(4-Bromo-2-chlorophenyl)-O-ethyl S-propyl phosphorothioate] | 41198-08-7 | No | In review |
| 111601 | Oxyfluorfen [2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene] | 42874-03-3 | No | In review |
| 111901 | Imazalil [1-(2-(2,4-Dichlorophenyl)-2-(2-propenyloxy)ethyl)-1H-imidazole] | 35554-44-0 | No | No |
| 112802 | Bromothalin [N-Methyl-2,4-dinitro-n-(2,4,6-tribromophenyl)-6-(trifluoromethyl)benzenamine] | 63333-35-7 | No | No |
| 113201 | Vinclozolin [3-(3,5-Dichlorophenyl)-5-ethenyl-5-methyl-2,4-oxazolidinedione (9CA)] | 50471-44-8 | No | No |
| 119001 | Fenridazon [Potassium 1-(p-chlorophenyl)-1,4-dihydro-6-methyl-4-oxo- pyridazine-3-carboxylate] | 83588-43-6 | No | In review |
| 123901 | Tridiphan [2-(3,5-Dichlorophenyl)-2-(2,2,2-trichloroethyl) oxirane] | 58138-08-2 | No | No |
| 125601 | Paclobutrazol | 76738-62-0 | No | No |
| 128838 | Linalool | 78-70-6 | No | In review |
| 206600 | Fenarimol [a-(2-chlorophenyl)-a-(4-chlorophenyl)-5-pyrimidinemethanol] | 60168-88-9 | No | No |

-- = No information given

Table 8-30. Status of second pesticide data call-in: pesticides suspected of being contaminated with dioxins

| Shaughnessey code | Pesticide [active ingredient] | CAS number | Support withdrawn | Testing required |
|-------------------|--|---------------|-------------------|------------------|
| 29801 | Dicamba [3,6-dichloro-o-anisic acid] | 1918-00-9 | No | Yes |
| 29802 | Dicamba dimethylamine [3,6-dichloro-o-anisic acid] | 2300-66-5 | No | Yes |
| 29803 | Diethanolamine dicamba [3,6-dichloro-2-anisic acid] | 25059-78-3 | Yes | -- |
| 30001 | 2,4-Dichlorophenoxyacetic acid | 94-75-7 | No | Yes |
| 30002 | Lithium 2,4-dichlorophenoxyacetate | 3766-27-6 | No | No |
| 30003 | Potassium 2,4-dichlorophenoxyacetate | 14214-89-2 | Yes | -- |
| 30004 | Sodium 2,4-dichlorophenoxyacetate | 2702-72-9 | No | No |
| 30005 | Ammonium 2,4-dichlorophenoxyacetate | 2307-55-3 | Yes | -- |
| 30010 | Alkanol* amine 2,4-dichlorophenoxyacetate *(salts of the ethanol and isopropanol series) | Not available | Yes | -- |
| 30011 | Alkyl* amine 2,4-dichlorophenoxyacetate *(100% C12) | 2212-54-6 | Yes | -- |
| 30013 | Alkyl* amine 2,4-dichlorophenoxyacetate *(100% C14) | 28685-18-9 | Yes | -- |
| 30014 | Alkyl* amine 2,4-dichlorophenoxyacetate *(as in fatty acids of tall oil) | Not available | Yes | -- |
| 30016 | Diethanolamine 2,4-dichlorophenoxyacetate | 5742-19-8 | No | No |
| 30017 | Diethylamine 2,4-dichlorophenoxyacetate | 20940-37-8 | Yes | -- |
| 30019 | Dimethylamine 2,4-dichlorophenoxyacetate | 2008-39-1 | No | No |
| 30020 | N,N-Dimethylethylamine 2,4-dichlorophenoxyacetate | 53535-36-7 | Yes | -- |
| 30021 | Ethanolamine 2,4-dichlorophenoxyacetate | 3599-58-4 | Yes | -- |
| 30023 | Heptylamine 2,4-dichlorophenoxyacetate | 37102-63-9 | Yes | -- |
| 30024 | Isopropanolamine 2,4-dichlorophenoxyacetate | 6365-72-6 | Yes | -- |
| 30025 | Isopropylamine 2,4-dichlorophenoxyacetate | 5742-17-6 | No | No |
| 30028 | Morpholine 2,4-dichlorophenoxyacetate | 6365-73-7 | Yes | -- |
| 30029 | N-Oleyl-1,3-propylenediamine 2,4-dichlorophenoxyacetate | 2212-59-1 | Yes | -- |
| 30030 | Octylamine 2,4-dichlorophenoxyacetate | 2212-53-5 | Yes | -- |
| 30033 | Triethanolamine 2,4-dichlorophenoxyacetate | 2569-01-9 | Yes | -- |

Table 8-30. Status of second pesticide data call-in: pesticides suspected of being contaminated with dioxins (continued)

| Shaughnessey code | Pesticide [active ingredient] | CAS number | Support withdrawn | Testing required |
|-------------------|--|------------|-------------------|------------------|
| 30034 | Triethylamine 2,4-dichlorophenoxyacetate | 2646-78-8 | No | No |
| 30035 | Triisopropanolamine 2,4-dichlorophenoxyacetate | 32341-80-3 | No | No |
| 30039 | N,N-Dimethyl oleyl-linoleyl amine 2,4-dichlorophenoxyacetate | 55256-32-1 | Yes | -- |
| 30052 | Butoxyethoxypropyl 2,4-dichlorophenoxyacetate | 1928-57-0 | Yes | -- |
| 30053 | Butoxyethyl 2,4-dichlorophenoxyacetate | 1929-73-3 | No | No |
| 30055 | Butoxypropyl 2,4-dichlorophenoxyacetate | 1928-45-6 | Yes | -- |
| 30056 | Butyl 2,4-dichlorophenoxyacetate | 94-80-4 | Yes | -- |
| 30062 | Isobutyl 2,4-dichlorophenoxyacetate | 1713-15-1 | Yes | -- |
| 30063 | Isooctyl(2-ethylhexyl) 2,4-dichlorophenoxyacetate | 1928-43-4 | No | Yes |
| 30064 | Isooctyl(2-ethyl-4-methylpentyl) 2,4-dichlorophenoxyacetate | 25168-26-7 | Yes | -- |
| 30065 | Isooctyl(2-octyl) 2,4-dichlorophenoxyacetate | 1917-97-1 | Yes | -- |
| 30066 | Isopropyl 2,4-dichlorophenoxyacetate | 94-11-1 | No | No |
| 30072 | Propylene glycol butyl ether 2,4-dichlorophenoxyacetate | 1320-18-9 | Yes | -- |
| 30801 | 4-(2,4-Dichlorophenoxy)butyric acid | 94-82-6 | No | Yes |
| 30804 | Sodium 4-(2,4-dichlorophenoxy)butyrate | 10433-59-7 | No | No |
| 30819 | Dimethylamine 4-(2,4-dichlorophenoxy)butyrate | 2758-42-1 | No | No |
| 30853 | Butoxyethanol 4-(2,4-dichlorophenoxy)butyrate | 32357-46-3 | Yes | -- |
| 30856 | Butyl 4-(2,4-dichlorophenoxy)butyrate | 6753-24-8 | Yes | -- |
| 30863 | Isooctyl 4-(2,4-dichlorophenoxy)butyrate | 1320-15-6 | Yes | -- |
| 31401 | 2-(2,4-Dichlorophenoxy)propionic acid | 120-36-5 | No | Yes |
| 31419 | Dimethylamine 2-(2,4-dichlorophenoxy)propionate | 53404-32-3 | No | No |
| 31453 | Butoxyethyl 2-(2,4-dichlorophenoxy)propionate | 53404-31-2 | No | No |
| 31463 | Isooctyl 2-(2,4-dichlorophenoxy)propionate | 28631-35-8 | No | No |
| 31501 | MCPD acid [2-(2-Methyl-4-chlorophenoxy)propionic acid] | 7085-19-0 | No | Yes |

Table 8-30. Status of second pesticide data call-in: pesticides suspected of being contaminated with dioxins (continued)

| Shaughnessey code | Pesticide [active ingredient] | CAS number | Support withdrawn | Testing required |
|-------------------|--|---------------|-------------------|------------------|
| 31519 | MCPP, DMA [Dimethylamine 2-(2-methyl-4-chlorophenoxy)propionate] | 32351-70-5 | No | No |
| 35301 | Bromoxynil [3,5-dibromo-4-hydroxybenzonitrile] | 1689-84-5 | No | Yes |
| 44901 | Hexachlorophene [2,2'-Methylenebis(3,4,6-trichlorophenol)] | 70-30-4 | Yes | -- |
| 44902 | Hexachlorophene, Na salt [Monosodium 2,2'-methylenebis(3,4,6-trichlorophenate)] | 5736-15-2 | Yes | -- |
| 44904 | Hexachlorophene, K salt [Potassium 2,2'-methylenebis(3,4,6-trichlorophenate)] | 67923-62-0 | Yes | -- |
| 54901 | Irgasan [5-Chloro-2-(2,4-dichlorophenoxy)phenol] | 3380-34-5 | No | Yes |
| 63004 | Tetrachlorophenols | 25167-83-3 | Yes | -- |
| 63005 | Tetrachlorophenols, sodium salt | 25567-55-9 | Yes | -- |
| 63006 | Tetrachlorophenols, alkyl* amine salt*(as in fatty acids of coconut oil) | Not available | Yes | -- |
| 63007 | Tetrachlorophenols, potassium salt | 53535-27-6 | Yes | -- |
| 64203 | Bithionolate sodium [Disodium 2,2'-thiobis(4,6-dichlorophenate)] | 6385-58-6 | Yes | -- |
| 64212 | Phenachlor [2,4,6-Trichlorophenol] | 88-06-2 | Yes | -- |
| 64219 | Potassium 2,4,6-trichlorophenate | 2591-21-1 | Yes | -- |
| 64220 | 2,4,6-Trichlorophenol, sodium salt | 3784-03-0 | Yes | -- |
| 64501 | Phenothiazine | 92-84-2 | Yes | -- |
| 78701 | Dacthal-DCPA [Dimethyl tetrachloroterephthalate] | 1861-32-1 | No | Yes |
| 79401 | Endosulfan [hexachlorohexahydromethano-2,4,3-benzodioxathiepin-3-oxide] | 115-29-7 | No | No |
| 82501 | Silvex [2-(2,4,5-trichlorophenoxy)propionic acid] | 93-72-1 | Yes | -- |
| 83701 | Tetrachlorvinphos [2-Chloro-1-(2,4,5-trichlorophenyl)vinyl dimethyl phosphate] | 961-11-5 | No | Yes |
| 104101 | Edolan [Sodium 1,4',5'-trichloro-2'-(2,4,5-trichlorophenoxy) methanesulfonamide] | 69462-14-2 | Yes | -- |

-- = No information given

Table 8-31. Summary of analytical data submitted to EPA in response to pesticide data call-in(s)

| Shaughnessey code | Pesticide | | Number of positive submissions ^a to date |
|-------------------|------------------------|---|---|
| | Common name | Chemical name | |
| 019201 | MCPB, 4-butyric acid | 4-(2-methyl-4-chlorophenoxy)butyric acid | 0 |
| 019401 | 4-CPA | 4-Chlorophenoxyacetic acid | 0 |
| 027401 | Dichlobenil | 2,6-Dichlorobenzonitrile | 0 |
| 029801 | Dicamba | 3,6-Dichloro-o-anisic acid | 0 |
| 029802 | Dicamba, dimethylamine | 3,6-Dichloro-o-anisic acid, dimethylamine salt | 0 |
| 030001 | 2,4-D | 2,4-Dichlorophenoxy acetic acid | 2 |
| 030063 | 2,4-D, 2EH | Isooctyl(2-ethylhexyl)2,4-dichlorophenoxyacetate | 1 |
| 030801 | 2,4-DB | 4-(2,4-Dichlorophenoxy)butyric acid | 0 |
| 031301 | DCNA | 2,6-Dichloro-4-nitroaniline | Pending |
| 031401 | 2,4-DP | 2-(2,4-Dichlorophenoxy)propionic acid | 0 |
| 031501 | Mecoprop (MCP) | 2-(2-methyl-4-chlorophenoxy)propionic acid | 0 |
| 035301 | Bromoxynil | 3,5-Dibromo-4-hydroxybenzonitrile | 0 |
| 054901 | Irgasan | 5-Chloro-2-(2,4-dichlorophenoxy)phenol | 0 |
| 078701 | Dacthal (DCPA) | Dimethyl tetrachloroterephthalate | Pending |
| 081901 | Chlorothalonil | Tetrachloroisophthalonitrile | Pending |
| 083701 | Tetrachlorvinphos | 2-Chloro-1-(2,4,5-trichlorophenyl)vinyl dimethyl phosphate | 0 |
| 108201 | Diflubenzuron | N-(((4-chlorophenyl)amino)carbonyl)-2,6-difluorobenzamide | 0 |
| 109001 | Oxadiazon | 2-Tert-butyl-4(2,4-dichloro-5-isopropoxyphenyl)-delta2-1,3,4-oxadiazoline-5-one | Pending |
| 110902 | Dichlofop-methyl | Methyl-2-(4-(2,4-dichlorophenoxy)phenoxy) propanoate | 0 |

^a“Positive” is defined as the detection of any congener at a concentration equal to or exceeding the limits of quantitation listed in Table 8-23.

Sources: U.S. EPA (1995a); personal communication from S. Funk, U.S. EPA, to D. Cleverly, U.S. EPA, March 27, 1996.

Table 8-32. Summary of results for CDDs and CDFs in technical 2,4-D and 2,4-D ester herbicides

| Congener | EPA LOQ^a (µg/kg) | Total no. of technicals | Number of technicals greater than LOQ | Observed maximum conc. (µg/kg) | Average conc.^b (µg/kg) |
|--|--|--------------------------------|--|---|--|
| 2,3,7,8-TCDD | 0.1 | 8 | 2 | 0.13 | 0.06 |
| 1,2,3,7,8-PeCDD | 0.5 | 8 | 3 | 2.6 | 0.78 |
| 1,2,3,4,7,8-HxCDD | 2.5 | 8 | 0 | 0.81 | 0.31 |
| 1,2,3,6,7,8-HxCDD | 2.5 | 8 | 0 | 0.77 | 0.39 |
| 1,2,3,7,8,9-HxCDD | 2.5 | 8 | 0 | 0.68 | 0.24 |
| 1,2,3,4,6,7,8-HpCDD | 100 | 8 | 0 | 1.5 | 0.21 |
| OCDD | -- | -- | -- | -- | -- |
| 2,3,7,8-TCDF | 1 | 8 | 0 | 0.27 | 0.07 |
| 1,2,3,7,8-PeCDF | 5 | 8 | 0 | 0.62 | 0.38 |
| 2,3,4,7,8-PeCDF | 5 | 7 | 0 | 0.73 | 0.07 |
| 1,2,3,4,7,8-HxCDF | 25 | 8 | 0 | 1.6 | 0.36 |
| 1,2,3,6,7,8-HxCDF | 25 | 8 | 0 | 1.2 | 0.11 |
| 1,2,3,7,8,9-HxCDF | 25 | 8 | 0 | 1.4 | 0.16 |
| 2,3,4,6,7,8-HxCDF | 25 | 8 | 0 | 1.1 | 0.14 |
| 1,2,3,4,6,7,8-HpCDF | 1,000 | 8 | 0 | 8.3 | 2.17 |
| 1,2,3,4,7,8,9-HpCDF | 1,000 | 8 | 0 | 1.2 | 0.18 |
| OCDF | -- | -- | -- | -- | -- |
| TOTAL^c | | | | | 5.6 |
| I-TEQ_{DF} | | | | | 0.7 |
| TEQ_{DF}-WHO₉₈ | | | | | 1.1 |

^aLOQ required by EPA in the data call-in.

^bAverage of the mean results for multiple analyses of four technical 2,4-D and/or 2,4-D ester products for which detectable CDD/CDF congener concentrations less than the LOQs were quantified; nondetect values were assumed to be zero.

^cTotal equals the sum of the individual congener averages.

LOQ = Limit of quantitation

-- = Analyses not performed

Source: U.S. EPA Office of Pesticide Program file.

Table 8-33. CDD/CDF concentrations in samples of 2,4-D and pesticide formulations containing 2,4-D (µg/kg)

| Congener/Congener group | Acbar Super (Gaza City ^a) | Amco Super (Gaza City ^a) | (Bethlehem) | Chimprom (Russia) | Dragon Lawn Weed Killer | KGRO (U.S.) | Pro Care Premium (U.S.) | Ortho Weed-B-Gone (U.S.) | Sigma Co. (U.S.) | American Brand Chemical Co. (U.S.) | Ishihara Sangyo Kaisha, Ltd. (Japan) | Nissan Chemical Industries, Ltd. (Japan) |
|---|---------------------------------------|--------------------------------------|-------------|-------------------|-------------------------|-------------|-------------------------|--------------------------|------------------|------------------------------------|--------------------------------------|--|
| 2,3,7,8-TCDD | ND (0.1) | ND (0.1) | ND (0.1) | ND (0.02) | ND (0.001) | -- | -- | -- | -- | -- | 0.0021 | ND (0.002) |
| 1,2,3,7,8-PeCDD | 0.1 | ND (0.1) | 1.2 | 0.03 | 0.0014 | -- | -- | -- | -- | -- | 0.011 | ND (0.002) |
| 1,2,3,4,7,8-HxCDD | ND (0.1) | ND (0.1) | ND (0.1) | 0.02 | ND (0.001) | -- | -- | -- | -- | -- | ND (0.005) | ND (0.005) |
| 1,2,3,6,7,8-HxCDD | ND (0.1) | 0.2 | 0.6 | 0.05 | 0.0024 | -- | -- | -- | -- | -- | ND (0.005) | ND (0.005) |
| 1,2,3,7,8,9-HxCDD | ND (0.1) | ND (0.1) | 0.4 | ND (0.02) | 0.001 | -- | -- | -- | -- | -- | ND (0.005) | ND (0.005) |
| 1,2,3,4,6,7,8-HpCDD | 0.1 | 1.2 | 0.3 | 0.23 | 0.0017 | -- | -- | -- | -- | -- | ND (0.005) | ND (0.005) |
| OCDD | 0.1 | 2.6 | 0.1 | 0.85 | 0.0063 | -- | -- | -- | -- | -- | ND (0.01) | ND (0.01) |
| 2,3,7,8-TCDF | 0.3 | ND (0.1) | ND (0.1) | ND (0.1) | 0.0036 | -- | -- | -- | -- | -- | ND (0.002) | ND (0.002) |
| 1,2,3,7,8-/1,2,3,4,8-PeCDF | ND (0.1) | 0.2 | 0.7 | 1.2 | 0.001 | -- | -- | -- | -- | -- | 0.0038 | ND (0.002) |
| 2,3,4,7,8-PeCDF | ND (0.1) | ND (0.1) | 0.1 | 0.06 | 0.0011 | -- | -- | -- | -- | -- | ND (0.002) | ND (0.002) |
| 1,2,3,4,7,8-/1,2,3,4,7,9-HxCDF | ND (0.1) | 0.1 | 0.4 | 0.08 | 0.0013 | -- | -- | -- | -- | -- | ND (0.005) | ND (0.005) |
| 1,2,3,6,7,8-HxCDF | ND (0.1) | ND (0.1) | 0.1 | 0.11 | ND (0.001) | -- | -- | -- | -- | -- | ND (0.005) | ND (0.005) |
| 1,2,3,7,8,9-HxCDF | ND (0.1) | ND (0.1) | ND (0.1) | ND (0.02) | ND (0.001) | -- | -- | -- | -- | -- | ND (0.005) | ND (0.005) |
| 2,3,4,6,7,8-HxCDF | ND (0.1) | ND (0.1) | 0.1 | 0.05 | 0.0011 | -- | -- | -- | -- | -- | ND (0.005) | ND (0.005) |
| 1,2,3,4,6,7,8-HpCDF | 0.1 | 0.8 | 0.1 | 0.24 | 0.0016 | -- | -- | -- | -- | -- | ND (0.005) | ND (0.005) |
| 1,2,3,4,7,8,9-HpCDF | ND (0.1) | ND (0.1) | ND (0.1) | 0.02 | ND (0.001) | -- | -- | -- | -- | -- | ND (0.005) | ND (0.005) |
| OCDF | 0.2 | 3.8 | 0.4 | 0.46 | 0.0039 | -- | -- | -- | -- | -- | ND (0.010) | ND (0.01) |
| Total 2,3,7,8-CDD (nondetect = 0) | 0.3 | 4 | 2.6 | 1.18 | 0.0128 | 0.0144 | 0.0143 | 0.0091 | 0.127 | 0.0278 | -- | -- |
| Total 2,3,7,8-CDF (nondetect = 0) | 0.6 | 4.9 | 1.9 | 2.22 | 0.0136 | 0.1628 | 0.4253 | 0.1095 | 3.0507 | 0.0822 | -- | -- |
| Total I-TEQ _{DF} (nondetect = 0) ^b | 0.082 | 0.066 | 0.85 | 0.142 | 0.0023 | 0.0009 | 0.0012 | 0.0014 | 0.0013 | 0.0019 | 0.0078 | ND |
| Total TEQ _{DF} -WHO ₉₈ (nondetect = 0) ^b | 0.134 | 0.061 | 1.449 | 0.156 | 0.003 | | | | | | 0.013 | ND |
| Total TCDD | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.041 | ND (0.002) |
| Total PeCDD | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.018 | ND (0.002) |
| Total HxCDD | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.008 | ND (0.005) |
| Total HpCDD | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | ND (0.005) | ND (0.005) |
| Total OCDD | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | ND (0.01) | ND (0.01) |
| Total TCDF | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2.7 | 0.0093 |
| Total PeCDF | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.89 | ND (0.002) |
| Total HxCDF | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.019 | ND (0.005) |
| Total HpCDF | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.006 | ND (0.005) |
| Total OCDF | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | ND (0.01) | ND (0.01) |
| Total CDD/CDF | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 3.7 | 0.0093 |

^a2,4-D manufactured in Europe and packaged in Palestine.^bCalculated assuming nondetect values are zero.

ND = not detected (value in parenthesis is the detection limit)

**Table 8-33. CDD/CDF concentrations in samples of 2,4-D and pesticide formulations containing 2,4-D (µg/kg)
(continued)**

-- = No information given

Sources: Schecter et al. (1997); Maunaga et al. (2001).

Table 8-34. Mean CDD/CDF measurements in effluents from nine U.S. publicly owned treatment works (POTWs)

| Congener/congener group | No. of detections/samples | Range of DLs (pg/L) | Range of detected concentrations (POTW mean basis) (pg/L) | | Overall mean concentrations ^a | |
|--|---------------------------|---------------------|---|---------|--|------------------------------|
| | | | Minimum | Maximum | Nondetect set to 0 (pg/L) | Nondetect set to ½ DL (pg/L) |
| 2,3,7,8-TCDD | 0/30 | 0.31–8.8 | ND | ND | 0 | 0.98 |
| 1,2,3,7,8-PeCDD | 0/30 | 0.45–15 | ND | ND | 0 | 1.32 |
| 1,2,3,4,7,8-HxCDD | 0/30 | 0.43–9.8 | ND | ND | 0 | 1.38 |
| 1,2,3,6,7,8-HxCDD | 0/30 | 0.81–10 | ND | ND | 0 | 1.42 |
| 1,2,3,7,8,9-HxCDD | 0/30 | 0.42–9.7 | ND | ND | 0 | 1.31 |
| 1,2,3,4,6,7,8-HpCDD | 3/30 | 0.75–18 | ND | 5 | 1.06 | 3.61 |
| OCDD | 13/30 | 6.2–57 | ND | 99.75 | 29.51 | 37.95 |
| 2,3,7,8-TCDF | 1/27 | 0.74–4.4 | ND | 1.3 | 0.14 | 0.98 |
| 1,2,3,7,8-PeCDF | 1/30 | 0.64–9.4 | ND | 2 | 0.22 | 1.58 |
| 2,3,4,7,8-PeCDF | 1/30 | 0.61–14 | ND | 2.8 | 0.31 | 1.68 |
| 1,2,3,4,7,8-HxCDF | 1/30 | 0.25–6.8 | ND | 2.4 | 0.27 | 1.22 |
| 1,2,3,6,7,8-HxCDF | 1/30 | 0.23–6.8 | ND | 1.5 | 0.17 | 0.97 |
| 1,2,3,7,8,9-HxCDF | 1/30 | 0.57–10 | ND | 2 | 0.22 | 1.72 |
| 2,3,4,6,7,8-HxCDF | 1/30 | 0.25–7.9 | ND | ND | 0 | 0.93 |
| 1,2,3,4,6,7,8-HpCDF | 2/30 | 0.36–6.9 | ND | 4.6 | 0.68 | 1.83 |
| 1,2,3,4,7,8,9-HpCDF | 0/30 | 0.19–11 | ND | ND | 0 | 1.18 |
| OCDF | 1/30 | 0.86–28 | ND | 3.2 | 0.36 | 3.4 |
| Total 2,3,7,8-CDD | -- | -- | ND | 99.75 | 30.57 | 47.98 |
| Total 2,3,7,8-CDF | | | ND | 16.6 | 2.37 | 15.49 |
| Total I-TEQ _{DF} | | | ND | 2.42 | 0.29 | 3.66 |
| Total TEQ _{DF} -WHO ₉₈ | | | ND | 2.33 | 0.27 | 4.28 |
| Total TCDD | 4/27 | 1.2–8.8 | ND | 9.7 | 1.23 | 2.61 |
| Total PeCDD | 0/27 | 0.62–200 | ND | ND | 0 | 6.27 |
| Total HxCDD | 1/30 | 0.84–11 | ND | 1.7 | 0.19 | 1.93 |
| Total HpCDD | 3/30 | 0.75–18 | ND | 8.4 | 1.83 | 4.77 |
| Total OCDD | 13/30 | 6.2–57 | ND | 99.75 | 29.51 | 37.95 |
| Total TCDF | 2/30 | 0.39–6.8 | ND | 25 | 6.61 | 7.7 |
| Total PeCDF | 1/30 | 0.64–25 | ND | 20 | 2.22 | 4.72 |
| Total HxCDF | 1/30 | 0.93–17 | ND | 13 | 1.44 | 3.43 |
| Total HpCDF | 2/30 | 0.36–19 | ND | 4.6 | 0.68 | 2.41 |
| Total OCDF | 1/30 | 0.86–28 | ND | 3.2 | 0.36 | 3.4 |
| Total CDD/CDF | | | ND | 99.75 | 42 | 71.96 |

^aThe overall means are the means of the individual POTW mean concentrations rather than the means of the individual sample concentrations.

DL = Detection limit

ND = Not detected

-- = No information given

Source: CRWQCB (1996).

Table 8-35. Effluent concentrations of CDDs/CDFs from publicly owned treatment works in Mississippi (pg/L)

| Facility | 2,3,7,8-TCDD | 2,3,7,8-TCDF | 1,2,3,7,8-PeCDD | 2,3,4,7,8-PeCDF | Total HxCDD | Total HpCDD | OCDD | OCDF | Total I-TEQ |
|-------------------------|--------------|--------------|-----------------|-----------------|-------------|-------------|--------|-----------|-------------|
| Waynesboro | ND (0.17) | 0.18 | ND (0.2) | ND (0.1) | ND | 3.5 | 13 | 1.8 | 0.316 |
| Meridian | 0.18 | 0.12 | ND (0.16) | ND (0.09) | 1.3 | 7.6 | 58 | 1.8 | 0.445 |
| Pascagoula | ND (0.13) | 0.15 | ND (0.15) | 0.11 | ND | 0.82 | 3.6 | 0.46 | 0.264 |
| W. Biloxi | 0.18 | 0.24 | ND (0.15) | 0.082 | ND | 0.9 | 4 | ND (0.34) | 0.378 |
| Gulfport | 0.16 | 0.24 | ND (0.15) | 0.094 | ND | 2.3 | 9.9 | 0.78 | 0.371 |
| Laurel | ND (0.18) | 0.15 | ND (0.23) | ND (0.12) | ND | 2.9 | 38 | ND (0.48) | 0.334 |
| Brookhaven | ND (0.18) | 0.54 | 0.45 | 0.16 | 0.85 | 3.2 | 28 | 1.7 | 0.796 |
| Natchez | ND (0.16) | 0.41 | 0.6 | 0.34 | 2.5 | 2.4 | 9.1 | 1.8 | 1.03 |
| Picayune | ND (0.22) | 0.56 | ND (0.27) | ND (0.14) | 6.5 | 38 | 120 | 2 | 0.715 |
| Picayune ^a | ND (0.13) | 0.54 | ND (0.12) | ND (0.07) | 6 | 30 | 53 | 106 | 0.397 |
| Waveland | ND (0.18) | 17 | 0.22 | 0.66 | ND | 3 | 14 | | 2.4 |
| Corinth | ND (0.15) | 0.17 | ND (0.16) | ND (0.09) | 0.77 | 2.7 | 18 | 0.9 | 0.276 |
| New Augusta | ND (0.1) | 1.3 | 0.28 | 0.085 | 21 | 120 | 2500 | 1.1 | 3.84 |
| Beaumont | ND (0.1) | 0.14 | ND (0.13) | 0.088 | 0.64 | 2.4 | 11 | 0.66 | 0.274 |
| Leaksville | ND (0.12) | 0.72 | 0.25 | 0.15 | 8.9 | 46 | 780 | 3.2 | 1.6 |
| McLain | ND (0.06) | ND (0.05) | ND (0.10) | ND (0.06) | 2.5 | 14 | 200 | | 0.377 |
| Hattiesburg S | ND (0.16) | ND (0.24) | ND (0.24) | ND (0.11) | 1.2 | 4.5 | 59 | 0.77 | 0.32 |
| Hattiesburg N | ND (0.19) | 0.18 | ND (0.26) | ND (0.13) | 0.96 | 9.1 | 73 | 2.9 | 0.457 |
| Average (nondetect = 0) | 0.17 | 1.42 | 0.36 | 0.2 | 4.43 | 16.3 | 221.76 | 8.99 | 0.81 |

^aBlind double.

ND = Not detected (value in parenthesis is the detection limit)

Source: Rappe et al. (1998).

Table 8-36. CDD/CDF concentrations measured in EPA's 1998/1999 National Sewage Sludge Survey

| Congener | Percent detected | Maximum concentration detected (ng/kg) | Median concentration (ng/kg) | | Mean concentration (ng/kg) | |
|---------------------------|------------------|--|----------------------------------|-----------------------|----------------------------------|-----------------------|
| | | | Nondetect set to detection limit | Nondetect set to zero | Nondetect set to detection limit | Nondetect set to zero |
| 2,3,7,8-TCDD | 16 | 116 | 6.86 | 0 | -- | -- |
| 1,2,3,7,8-PeCDD | 18 | 736 | 9.84 | 0 | -- | -- |
| 1,2,3,4,7,8-HxCDD | 25 | 737 | 22.5 | 0 | -- | -- |
| 1,2,3,6,7,8-HxCDD | 49 | 737 | 27.3 | 0 | -- | -- |
| 1,2,3,7,8,9-HxCDD | 39 | 737 | 28 | 0 | -- | -- |
| 1,2,3,4,6,7,8-HpCDD | 98 | 52,500 | 335 | 335 | -- | -- |
| OCDD | 100 | 905,000 | 3,320 | 3,320 | -- | -- |
| 2,3,7,8-TCDF | 65 | 337 | 17 | 3.9 | -- | -- |
| 1,2,3,7,8-PeCDF | 22 | 736 | 9.6 | 0 | -- | -- |
| 2,3,4,7,8-PeCDF | 26 | 736 | 10.4 | 0 | -- | -- |
| 1,2,3,4,7,8-HxCDF | 43 | 1,500 | 28 | 0 | -- | -- |
| 1,2,3,6,7,8-HxCDF | 35 | 737 | 18 | 0 | -- | -- |
| 1,2,3,7,8,9-HxCDF | 16 | 1,260 | 18 | 0 | -- | -- |
| 2,3,4,6,7,8-HxCDF | 27 | 737 | 18 | 0 | -- | -- |
| 1,2,3,4,6,7,8-HpCDF | 71 | 7,100 | 57 | 36 | -- | -- |
| 1,2,3,4,7,8,9-HpCDF | 26 | 842 | 23 | 0 | -- | -- |
| OCDF | 80 | 69,500 | 110 | 80 | -- | -- |
| Total I-TEQ _{DF} | | 1,820 | 50.4 | 11.2 | 86 ^a | 50 ^a |
| Total 2,3,7,8-CDD/CDF | | -- | -- | -- | -- | -- |

^aValues presented by Rubin and White (1992) for 175 rather than 174 publicly owned treatment works.

-- = No information given

Source: U.S. EPA (1996a); for publicly owned treatment works with multiple samples, the pollutant concentrations were averaged before the summary statistics presented in the table were calculated.

Table 8-37. CDD/CDF concentrations measured in 99 sludges collected from U.S. publicly owned treatment works (POTWs) during 1994

| Congener | Percent detected | Maximum concentration detected (ng/kg) | Median concentration (ng/kg) | | Mean concentration (ng/kg) | |
|--|------------------|--|----------------------------------|-----------------------|---|------------------------------------|
| | | | Nondetect set to detection limit | Nondetect set to zero | Nondetect set to detection limit ^a | Nondetect set to zero ^a |
| 2,3,7,8-TCDD | 40 | 12.3 | 1.95 | 0 | 2.72 (2.4) | 1.71 (2.86) |
| 1,2,3,7,8-PeCDD | 23 | 37.5 | 8.23 | 0 | 10.9 (7.8) | 3.34 (7.43) |
| 1,2,3,4,7,8-HxCDD | 34 | 45.6 | 5.25 | 0 | 11.1 (8.13) | 6.03 (10.2) |
| 1,2,3,6,7,8-HxCDD | 87 | 130 | 25.6 | 24.7 | 33.8 (27.6) | 32.2 (28.8) |
| 1,2,3,7,8,9-HxCDD | 64 | 88.8 | 12.3 | 9.48 | 20.2 (17.7) | 17 (19.8) |
| 1,2,3,4,6,7,8-HpCDD | 98 | 5,380 | 642 | 642 | 981 (977) | 981 (977) |
| OCDD | 99 | 65,500 | 6,630 | 6,630 | 11,890 (12,540) | 11,890 (12,540) |
| 2,3,7,8-TCDF | 76 | 156 | 7.53 | 6.28 | 12.8 (19.6) | 11.1 (20.2) |
| 1,2,3,7,8-PeCDF | 21 | 60.3 | 7.91 | 0 | 10.7 (11.3) | 3.53 (9.36) |
| 2,3,4,7,8-PeCDF | 42 | 155 | 9.7 | 0 | 15.7 (19.8) | 10.5 (21.6) |
| 1,2,3,4,7,8-HxCDF | 48 | 170 | 11.5 | 0 | 20.4 (25.3) | 14 (25.9) |
| 1,2,3,6,7,8-HxCDF | 17 | 200 | 14 | 0 | 30.4 (53.6) | 5.13 (21.9) |
| 1,2,3,7,8,9-HxCDF | 4 | 115 | 7.53 | 0 | 11.1 (13.6) | 1.56 (11.7) |
| 2,3,4,6,7,8-HxCDF | 35 | 356 | 9.85 | 0 | 21.8 (40.4) | 13.6 (41) |
| 1,2,3,4,6,7,8-HpCDF | 64 | 1,460 | 91.7 | 31.8 | 223 (271) | 97.5 (207) |
| 1,2,3,4,7,8,9-HpCDF | 31 | 213 | 11.7 | 0 | 27.1 (34.8) | 15 (33.4) |
| OCDF | 93 | 11,200 | 286 | 281 | 786 (1,503) | 775 (1,506) |
| Average I-TEQ _{DF} (facility basis) ^b | | 246 | 49.6 | 33.4 | 64.5 (50.1) | 47.7 (44.7) |
| Total 2,3,7,8-CDD/CDF | | 73,520 | 7,916 | 7,881 | 14,110 (14,390) | 13,880 (14,200) |
| Average TEQ _{DF} -WHO ₉₈ (facility basis) ^b | | | 44.6 | 25.5 | 57.2 (44.4) | 36.3 (38.6) |

^aValue in parenthesis is the standard deviation.

^bFor POTWs with multiple samples, the sample TEQ concentrations were averaged to POTW averages before calculation of the total TEQ mean and median values presented in the table.

A total of 74 POTW average concentrations were used in the calculations. In addition, the following sample ID numbers were not included in the averaging because, according to Green et al. (1995), it was not possible to determine whether they were duplicate or multiple samples from other POTWs: 87, 88, 89, 90, 91, 97, 98, and 106.

Source: Green et al. (1995); Cramer et al. (1995).

Table 8-38. Sewage sludge concentrations from publicly owned treatment works in Mississippi (ng/kg dry matter)

| Facility | 2,3,7,8-TCDD | 2,3,7,8-TCDF | 1,2,3,7,8-PeCDD | 2,3,4,7,8-PeCDF | Total HxCDD | Total HpCDD | OCDD | OCDF | Total I-TEQ |
|-------------------------|--------------|--------------|-----------------|-----------------|-------------|-------------|---------|--------|-------------|
| Waynesboro | 2.1 | 2.9 | 3.5 | 1.4 | 85 | 920 | 7,400 | 410 | 23.7 |
| Meridian | ND (0.06) | 2.1 | 6.4 | 2.8 | 10 | 100 | 7,400 | 410 | 27.6 |
| Pascagoula | 2 | 3.6 | 5.3 | 3.5 | 170 | 970 | 4,300 | 170 | 26.4 |
| W. Biloxi | 0.84 | 2.4 | 3.2 | 1.3 | 78 | 280 | 1,800 | 70 | 13.7 |
| Gulfport | 1.9 | 9.1 | 9.5 | 3.4 | 200 | 1,100 | 7,700 | 310 | 30.9 |
| Laurel | 0.17 | 0.3 | 0.37 | 0.25 | 22 | 160 | 2,700 | 21 | 4.83 |
| Brookhaven | 2 | 2.5 | 11 | 2.5 | 130 | 1,400 | 9,300 | 230 | 36.7 |
| Natchez | ND (0.58) | 8.3 | 8.4 | ND (1.5) | 270 | 1,100 | 6,800 | 270 | 37.7 |
| Picayune | 5.3 | 69 | 74 | 24 | 17,000 | 250,000 | 480,000 | 16,000 | 1,270 |
| Picayune ^a | 4.1 | 66 | 60 | 17 | 16,000 | 210,000 | 420,000 | 17,000 | 1,240 |
| Waveland | 1.6 | 2.6 | 5.1 | 1.9 | 130 | 580 | 3,500 | 150 | 31.7 |
| Corinth | 0.3 | 1.8 | 0.97 | 0.93 | 42 | 230 | 3,300 | 36 | 7.4 |
| New Augusta | ND (0.13) | 0.17 | 0.15 | 0.094 | 21 | 140 | 1,400 | 8.8 | 2.67 |
| Beaumont | 0.17 | 0.67 | 0.78 | 0.37 | 59 | 470 | 1,900 | 42 | 6.18 |
| Leaksville | ND (0.051) | 0.14 | 0.32 | 0.11 | 16 | 92 | 560 | 26 | 2.26 |
| McLain | 0.076 | 0.17 | 0.11 | 0.031 | 39 | 140 | 2,600 | 0.74 | 3.55 |
| Hattiesburg S | 1 | 1.1 | 9.1 | 2.2 | 170 | 1,300 | 4,400 | 180 | 33 |
| Hattiesburg N | ND (0.035) | 1.7 | 4 | 2 | 310 | 3,600 | 27,000 | 980 | 70.4 |
| Average (nondetect = 0) | 1.2 | 9.7 | 11 | 3.4 | 1,900 | 26,000 | 55,000 | 2,000 | 116 ± 323 |

^aBlind double.

ND = Not detected (value in parenthesis is the detection limit)

Source: Rappe et al. (1998).

Table 8-39. CDD/CDF concentrations measured in 1999 from a publicly owned treatment works facility in Ohio

| Congener | Median Concentration (ng/kg) | |
|--|------------------------------|------------------------------------|
| | Nondetect set to zero | Nondetect set to ½ detection limit |
| 2,3,7,8-TCDD | ND | 0.0018 |
| 1,2,3,7,8-PeCD | ND | 0.0082 |
| 1,2,3,4,7,8-HxCDD | 2.67 | 2.67 |
| 1,2,3,6,7,8-HxCDD | 21.33 | 21.33 |
| 1,2,3,7,8,9-HxCDD | 30.33 | 30.33 |
| 1,2,3,4,6,7,8-HpCDD | 298 | 298 |
| OCDD | 2,963 | 2,963 |
| 2,3,7,8-TCDF | 26.67 | 26.67 |
| 1,2,3,7,8-PeCDF | 4.33 | 4.34 |
| 2,3,4,7,8-PeCDF | 10 | 10 |
| 1,2,3,4,7,8-HxCDF | 21 | 21 |
| 1,2,3,6,7,8-HxCDF | 5.33 | 5.33 |
| 1,2,3,7,8,9-HxCDF | ND | 0.0033 |
| 2,3,4,6,7,8-HxCDF | 9 | 9 |
| 1,2,3,4,6,7,8-HpCDF | 171 | 171 |
| 1,2,3,4,7,8,9-HpCDF | ND | 0.01 |
| OCDF | 364.67 | 364.67 |
| Average total TEQ _{DF} -WHO ₉₈ | 21.87 | 21.88 |

Source: U.S. EPA (2000).

Table 8-40. CDD/CDF concentrations measured in the EPA 2001 National Sewage Sludge Survey

| Congener | Mean concentration (ng/kg) | |
|--|----------------------------|------------------------------------|
| | Nondetect set to zero | Nondetect set to ½ detection limit |
| 2,3,7,8-TCDD | 1.41 | 1.1 |
| 1,2,3,7,8-PeCD | 5.76 | 4.57 |
| 1,2,3,4,7,8-HxCDD | 11.8 | 7.49 |
| 1,2,3,6,7,8-HxCDD | 21.3 | 15.1 |
| 1,2,3,7,8,9-HxCDD | 3.6 | 2.22 |
| 1,2,3,4,6,7,8-HpCDD | 492 | 273 |
| OCDD | 6,780 | 2,730 |
| 2,3,7,8-TCDF | 3.11 | 2.3 |
| 1,2,3,7,8-PeCDF | 2.61 | 1.5 |
| 2,3,4,7,8-PeCDF | 6.03 | 2.8 |
| 1,2,3,4,7,8-HxCDF | 1.37 | 1 |
| 1,2,3,6,7,8-HxCDF | 0.27 | 0 |
| 1,2,3,7,8,9-HxCDF | 5.21 | 2.6 |
| 2,3,4,6,7,8-HxCDF | 5.5 | 3.36 |
| 1,2,3,4,6,7,8-HpCDF | 9.13 | 2.8 |
| 1,2,3,4,7,8,9-HpCDF | 167 | 88.2 |
| OCDF | 802 | 279 |
| Average total TEQ _{DF} -WHO ₉₈ | 21.7 | 15.5 |

Source: U.S. EPA (2002a).

Table 8-41. Quantity of sewage sludge disposed of annually for the reference year 1987 by primary, secondary, and advanced treatment publicly owned treatment works and potential dioxin TEQ releases

| Use/disposal practice | Volume disposed of (thousands of dry metric tons/yr) | Percent of total volume | Potential dioxin release ^a (g of TEQ/yr) | |
|--|--|-------------------------|---|--------------------------------------|
| | | | I-TEQ _{DF} | TEQ _{DF} -WHO ₉₈ |
| Land application | 1,714 | 32 ^b | 84 | 62.2 |
| Distribution and marketing | 71 | 1.3 | 3.5 | 2.6 |
| Surface disposal site/other | 396 | 7.4 | 19.4 | 14.4 |
| Sewage sludge landfill | 157 | 2.9 | 7.7 | 5.7 |
| Co-disposal landfills ^c | 1,819 | 33.9 | 89.1 | 66 |
| Sludge incinerators and co-incinerators ^d | 865 | 16.1 | e | e |
| Ocean disposal | (336) ^f | (6.3) ^f | f | f |
| TOTAL | 5,357 | 100 | 204 | 151 |

^aPotential dioxin TEQ release for nonincinerated sludges was estimated by multiplying the sludge volume generated (column 2) by the average of the mean I-TEQ_{DF} concentrations in sludge reported by Rubin and White (1992) (i.e., 50 ng/kg dry weight) and Green et al. (1995) and Cramer et al. (1995) (47.7 ng/kg). The calculations of TEQ_{DF}-WHO₉₈ used the mean concentration of 36.3 ng TEQ_{DF}-WHO₉₈/kg for the results reported by Green et al. (1995) and Cramer et al. (1995).

^bIncludes 21.9% applied to agricultural land, 2.8% applied as compost, 0.6% applied to forestry land, 3.1% applied to "public contact" land, 1.2% applied to reclamation sites, and 2.4% applied in undefined settings.

^cLandfills used for disposal of sewage sludge and solid waste residuals.

^dCo-incinerators treat sewage sludge in combination with other combustible waste materials.

^eSee Section 3.5 for estimates of CDD/CDF releases to air from sewage sludge incinerators.

^fThe Ocean Dumping Ban Act of 1988 generally prohibited the dumping of sewage sludge into the ocean after December 31, 1991. Ocean dumping of sewage sludge ended in June 1992 (Federal Register, 1993b). The current method of disposal of the 336,000 metric tons of sewage sludge that were disposed of in the oceans in 1988 has not been determined.

Table 8-42. Quantity of sewage sludge disposed of annually for the reference year 1995 by primary, secondary, and advanced treatment publicly owned treatment works and potential dioxin TEQ releases

| Use/disposal practice | Volume disposed of (thousands of dry metric tons/yr) | Percent of total volume | Potential dioxin release ^a (g TEQ/yr) | |
|-----------------------------------|--|-------------------------|---|--------------------------------------|
| | | | I-TEQ _{DF} | TEQ _{DF} -WHO ₉₈ |
| Land application ^b | 2,500 | 41 | 122.3 | 90.7 |
| Advanced treatment ^c | 700 | 12 | 34.2 | 25.4 |
| Other beneficial use ^d | 500 | 7 | 24.5 | 18.2 |
| Surface disposal/landfill | 1,100 | 17 | 53.8 | 39.9 |
| Incineration | 1,400 | 22 | e | e |
| Other disposal method | 100 | 1 | 4.9 | 3.6 |
| TOTAL | 6,300 | 100 | 240 | 178 |

^aPotential dioxin TEQ release for nonincinerated sludges was estimated by multiplying the sludge volume generated (column 2) by the average of the mean I-TEQ_{DF} concentrations in sludge reported by Rubin and White (1992) (50 ng/kg dry weight) and Green et al. (1995) and Cramer et al. (1995) (47.7 ng/kg). The calculations of TEQ_{DF}-WHO₉₈ used the mean concentration of 36.3 ng TEQ_{DF}-WHO₉₈/kg for the results reported by Green et al. (1995) and Cramer et al. (1995).

^bWithout further processing or stabilization, such as composting.

^cSuch as composting.

^dEPA assumes that this category includes distribution and marketing (i.e., sale or give-away of sludge for use in home gardens). Based on the 1988 National Sewage Sludge Survey and 1988 Needs Survey, approximately 1.3% of the total volume of sewage disposed is distributed and marketed (Federal Register, 1993b). Therefore, it is estimated that 3 g TEQ_{DF}-WHO₉₈ (4 g I-TEQ_{DF}) were released through distribution and marketing in 1995.

^eSee Section 3.5 for estimates of CDD/CDF releases to air from sewage sludge incinerators.

Sources: Federal Register (1990, 1993b).

Table 8-43. Quantity of sewage sludge disposed of annually for reference year 2000 by primary, secondary, and advanced treatment publicly owned treatment works and potential dioxin TEQ releases

| Use/disposal practice | Volume disposed of (thousands of dry metric tons/yr) | Percent of total volume | Potential dioxin release ^a (g TEQ/yr) |
|-----------------------------------|--|-------------------------|---|
| | | | TEQ _{DF} -WHO ₉₈ |
| Land application ^b | 2,800 | 43 | 60.8 |
| Advanced treatment ^c | 800 | 12.5 | 17.4 |
| Other beneficial use ^d | 500 | 7.5 | 10.9 |
| Surface disposal/landfill | 900 | 14 | 19.5 |
| Incineration | 1,500 | 22 | e |
| Other disposal method | 100 | 1 | 2.17 |
| TOTAL | 6,600 | 100 | 111 |

^a Potential dioxin TEQ release for nonincinerated sludges was estimated by multiplying the sludge volume generated (i.e., column 2) by the average of the mean TEQ_{DF}-WHO₉₈ concentrations in sludge reported by U.S. EPA (2002).

^b Without further processing or stabilization, such as composting.

^c Such as composting.

^d EPA assumes that this category includes distribution and marketing (sale or give-away of sludge for use in home gardens). Based on the 1988 National Sewage Sludge Survey and 1988 Needs Survey, approximately 1.3% of the total volume of sewage disposed is distributed and marketed (Federal Register, 1993b). Therefore, it is estimated that 1.9 g TEQ_{DF}-WHO₉₈ were released through distribution and marketing in 2000.

^e See Section 3.5 for estimates of CDD/CDF releases to air from sewage sludge incinerators.

Table 8-44. Biosolids disposal practices for reference year 2000

| Use/disposal practice | Volume disposed of (thousands of dry metric tons/yr) | Percent of total volume |
|------------------------------|---|------------------------------------|
| Land application | 3,100 | 61 |
| Surface disposal/landfill | 940 | 18 |
| Incineration | 1,000 | 20 |
| Other | 64 | 1 |
| TOTAL | 5,100 | 100 |

Source: NRC (2002).

Table 8-45. CDD/CDF concentrations in Swedish liquid soap, tall oil, and tall resin

| Congener/congener group | Liquid soap (ng/L) | Tall oil (ng/kg) | Tall resin (ng/kg) |
|---|-------------------------------|-----------------------------|-------------------------------|
| 2,3,7,8-TCDD | ND (0.009) | 3.6 | ND (1) |
| 1,2,3,7,8-PeCDD | 0.4 | 5.3 | 3.1 |
| 1,2,3,4,7,8-HxCDD | ND (0.02) | ND (2) | ND (4) |
| 1,2,3,6,7,8-HxCDD | 0.32 | ND (2) | 810 |
| 1,2,3,7,8,9-HxCDD | 0.18 | ND (2) | 500 |
| 1,2,3,4,6,7,8-HpCDD | 1.9 | ND (1) | 5,900 |
| OCDD | 1 | 5.3 | 6,000 |
| 2,3,7,8-TCDF | 0.62 | 17 | ND (2) |
| 1,2,3,4,8-/1,2,3,7,8-PeCDF | 0.29 | 4.2 | ND (0.4) |
| 2,3,4,7,8-PeCDF | 0.2 | 1.9 | ND (0.5) |
| 1,2,3,4,7,8/9-HxCDF | 0.013 | 1.4 | 24 |
| 1,2,3,6,7,8-HxCDF | ND (0.004) | 0.7 | -- |
| 1,2,3,7,8,9-HxCDF | ND (0.004) | ND (0.7) | ND (1) |
| 2,3,4,6,7,8-HxCDF | ND (0.004) | ND (0.5) | ND (0.7) |
| 1,2,3,4,6,7,8-HpCDF | ND (0.005) | ND (0.8) | 10 |
| 1,2,3,4,7,8,9-HpCDF | ND (0.01) | ND (2) | 9.0 |
| OCDF | NA | NA | NA |
| Total 2,3,7,8-CDD ^a | 3.8 | 14.2 | 13,213.1 |
| Total 2,3,7,8-CDF ^a | 1.123 | 25.2 | 43 |
| Total I-TEQ _{DF} ^a | 0.447 | 9.4 | 200 |
| Total TEQ _{DF} -WHO ₉₈ ^a | 0.647 | 12 | 196 |
| Total TCDD | 0.12 | 31 | ND (1) |
| Total PeCDD | 15 | 380 | 25 |
| Total HxCDD | 3.4 | 3.3 | 6,800 |
| Total HpCDD | 3.6 | ND (1) | 11,000 |
| Total OCDD | 1 | 5.3 | 6,000 |
| Total TCDF | 1 | 26 | ND (2) |
| Total PeCDF | 1.3 | 41 | ND (0.5) |
| Total HxCDF | 0.15 | 4.9 | 56 |
| Total HpCDF | ND (0.01) | ND (2) | 19 |
| Total OCDF | NA | NA | NA |
| Total CDD/CDF ^a | 25.57 | 491.5 | 23,900 |

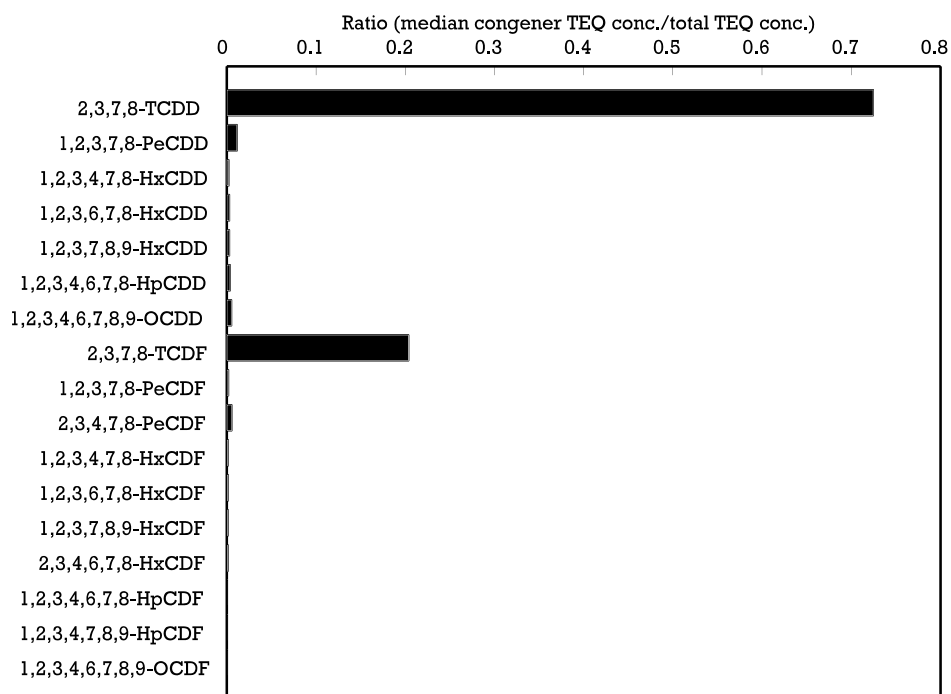
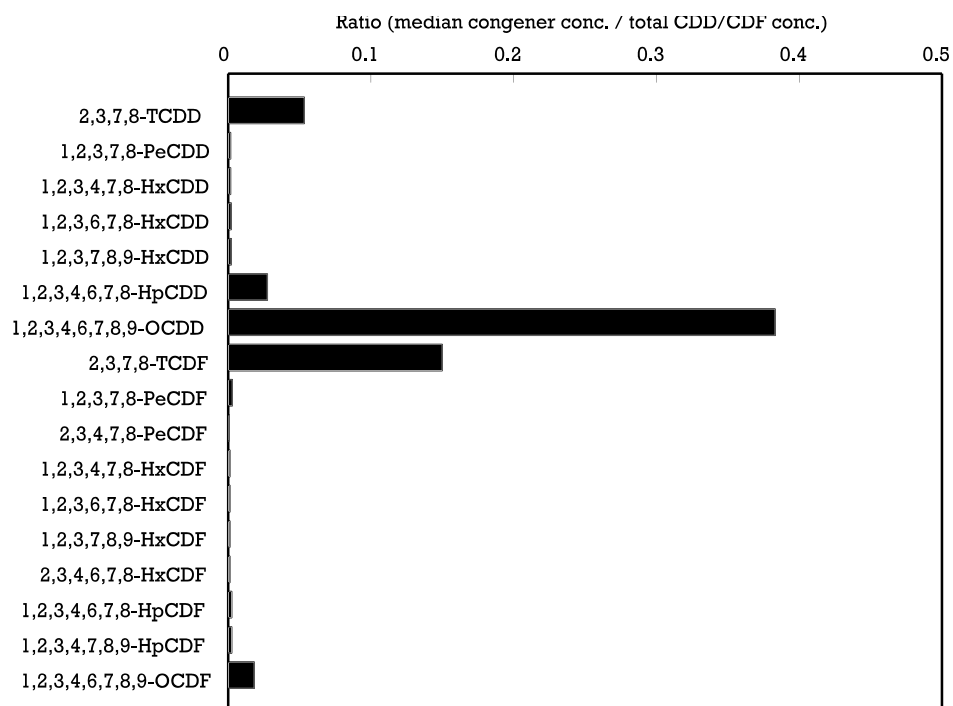
^aCalculations assume nondetect values are zero.

ND = Not detected (value in parenthesis is the detection limit)

NA = Not analyzed

-- = No information given

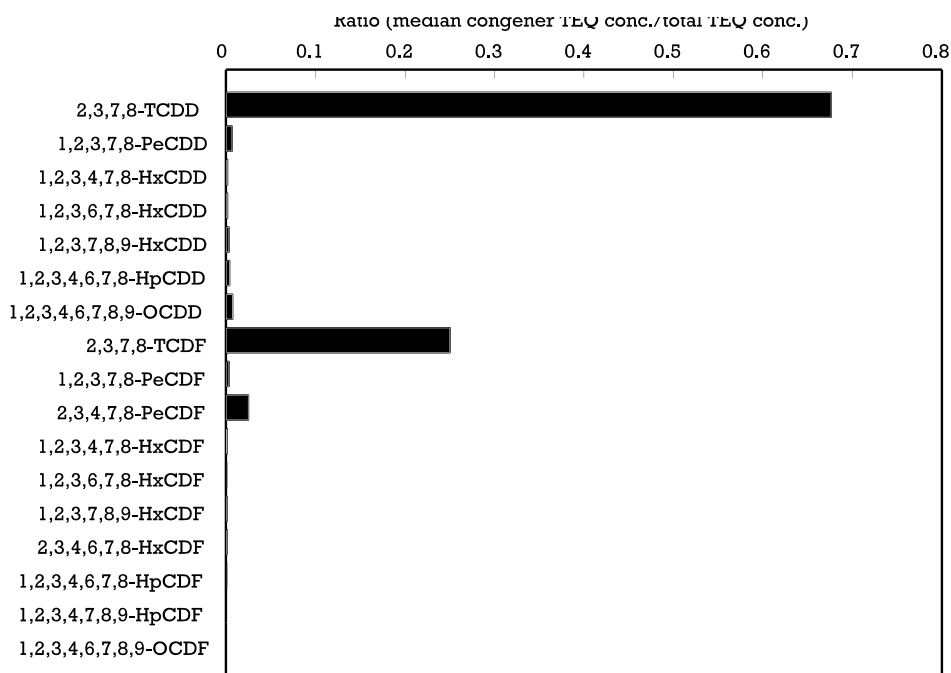
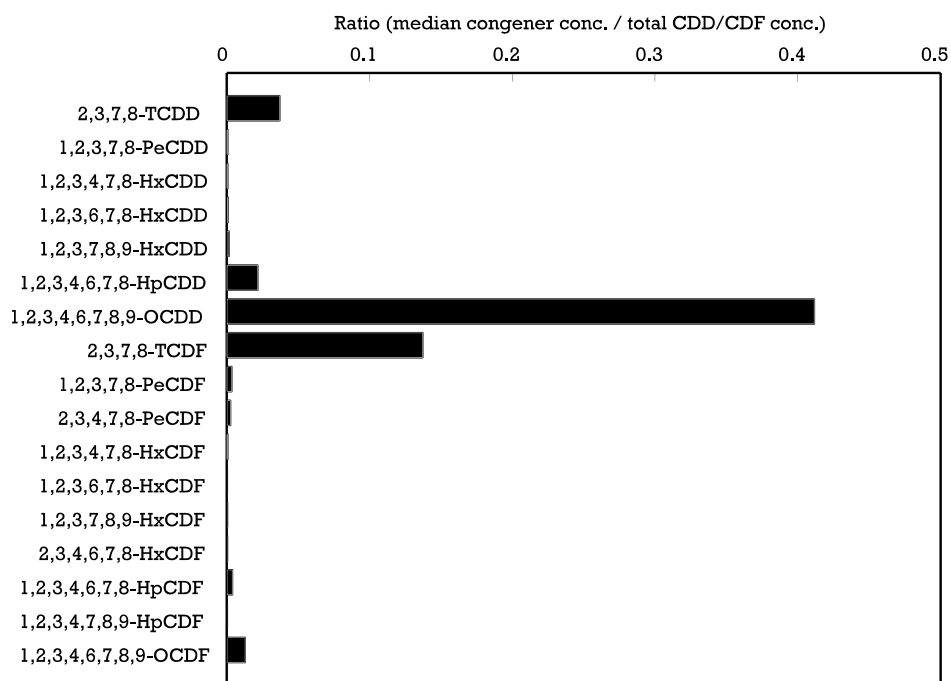
Source: Rappe et al. (1990c).



Nondetects set equal to 1/2 detection limit.

Figure 8-1. 104 Mill Study full congener analysis results for pulp.

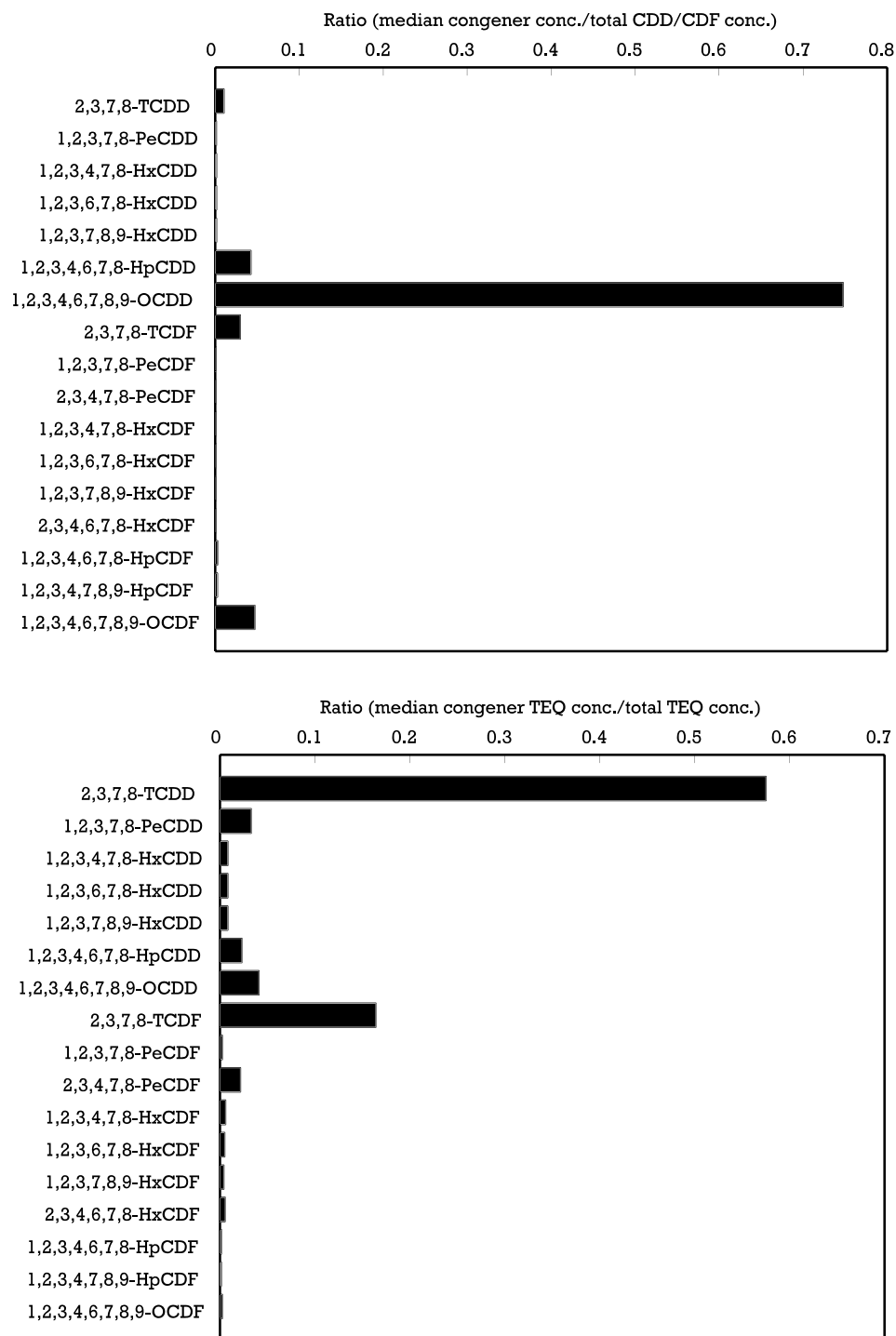
Source: Median concentrations from U.S. EPA (1990a).



Nondetects set equal to 1/2 detection limit.

Figure 8-2. 104 Mill Study full congener analysis results for sludge.

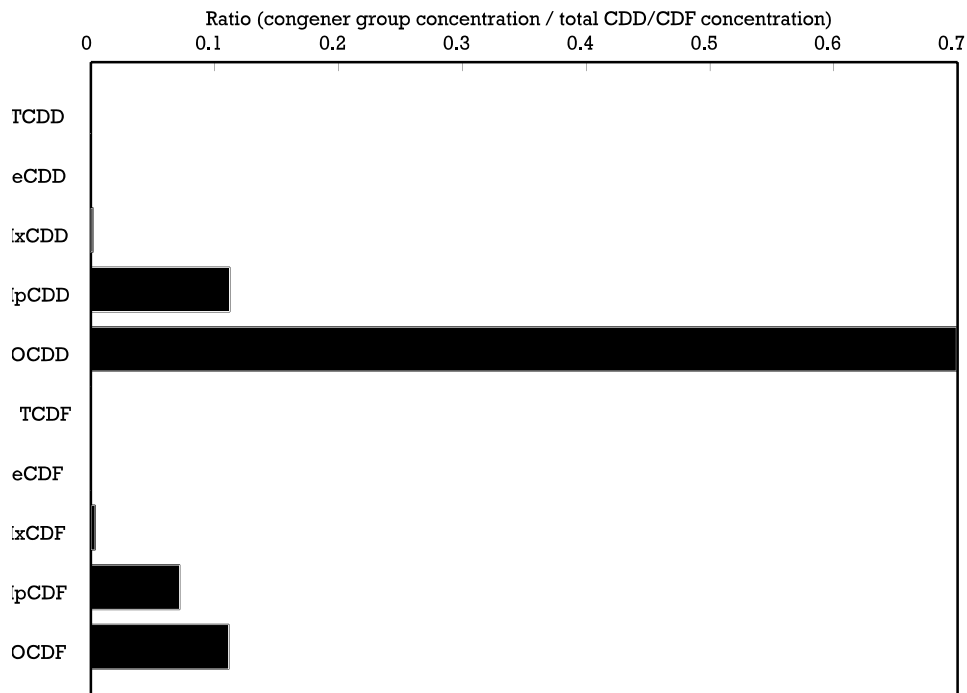
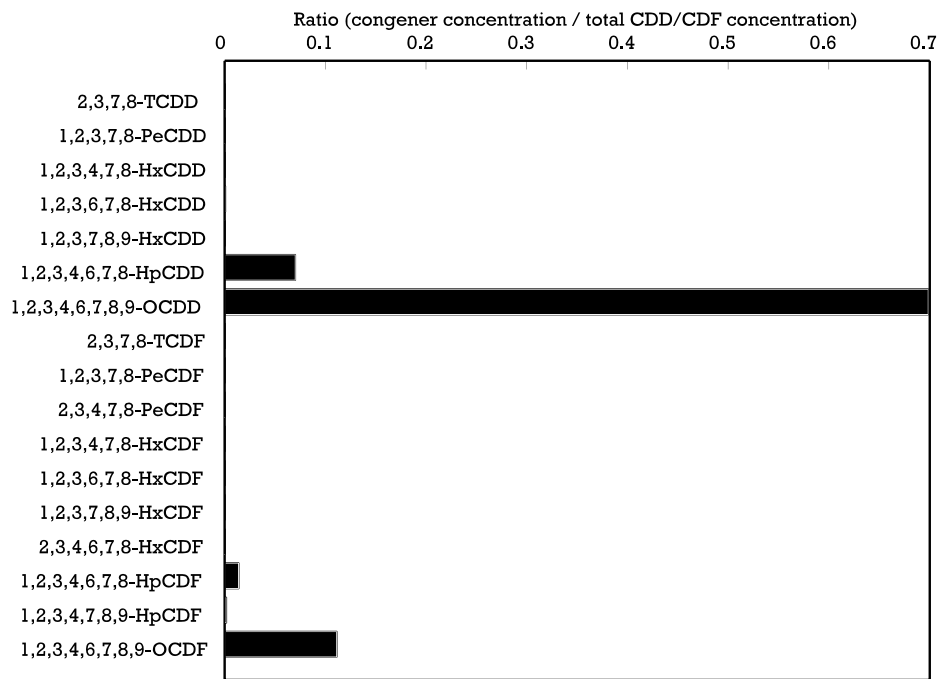
Source: Median concentrations from U.S. EPA (1990a).



Nondetects set equal to 1/2 detection limit.

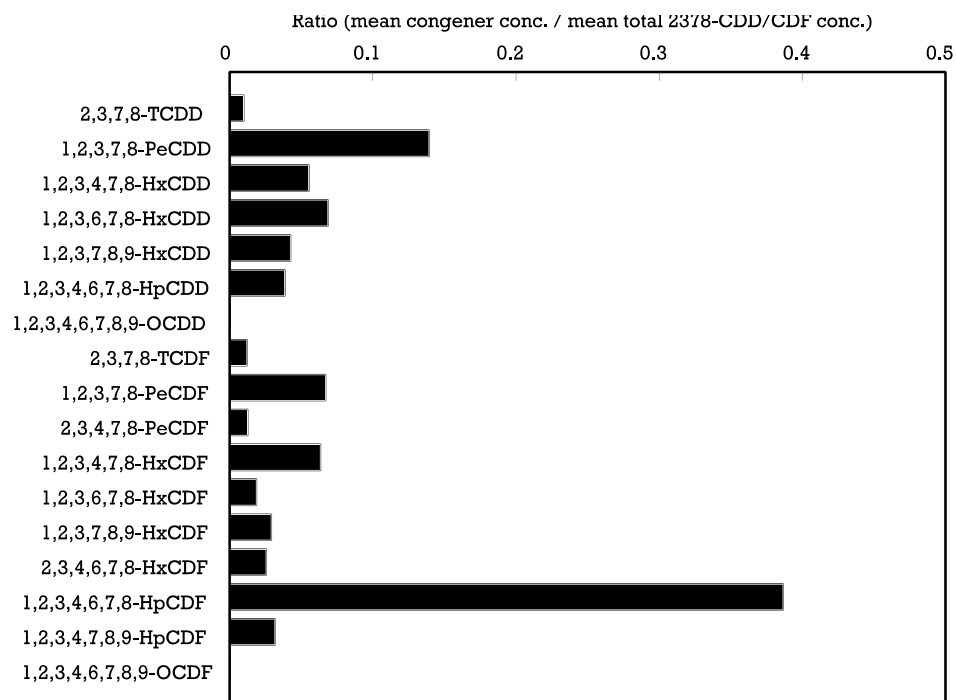
Figure 8-3. 104 Mill Study full congener analysis results for effluent

Source: Median concentrations from U.S. EPA (1990a).



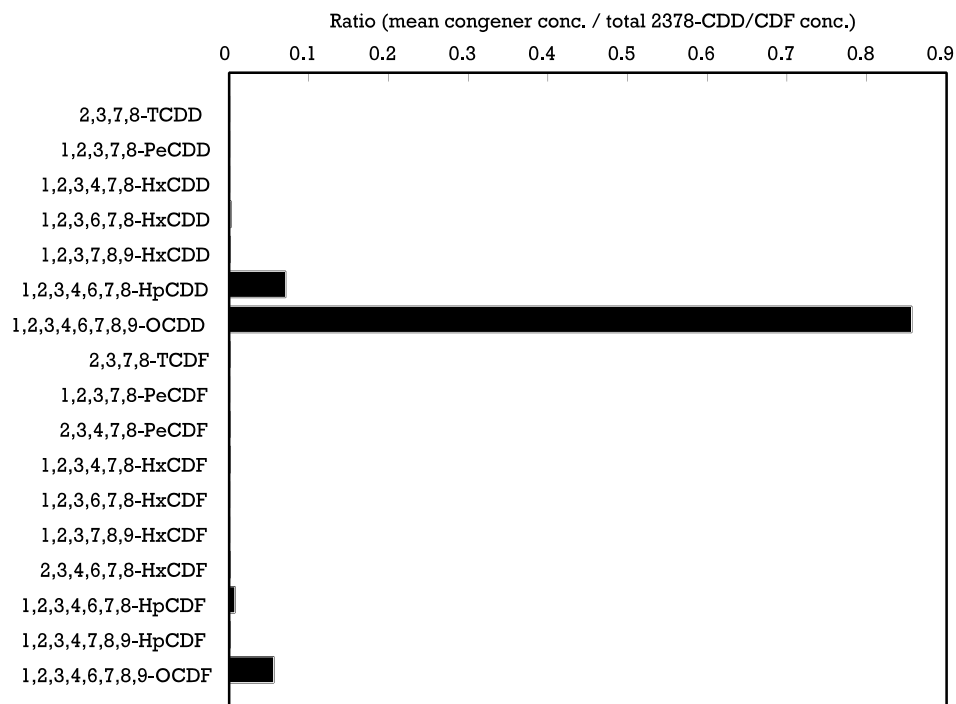
Nondetects set equal to zero.

Figure 8-4. Congener and congener group profiles for technical-grade PCP
(based on data reported in Table 8-7).



Nondetect set equal to zero.

Figure 8-5. Congener profile for 2,4-D (salts and esters) (based on mean concentrations reported in Table 8-26).



Nondetects set equal to 1/2 detection limit.

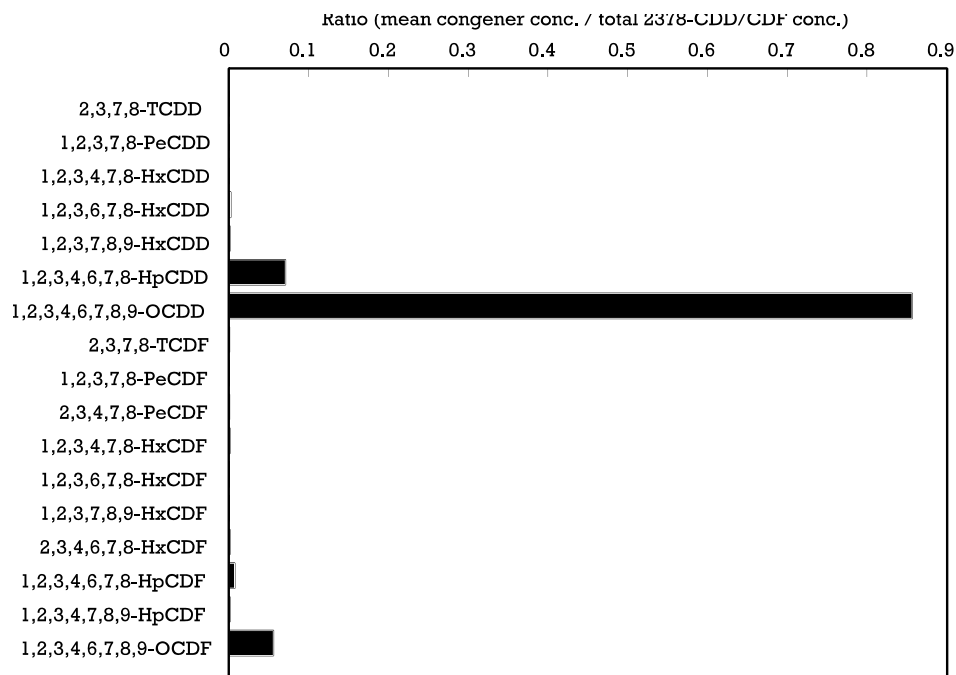


Figure 8-6. Congener profiles for sewage sludge

Source: Green et al. (1995).